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EDITED BY

JOSEPH G. HORNER, A.M.I.MECH.E.

AUTHOR OF "PRACTICAL METAL TURNING," "MODERN MILLING MACHINES," "PATTERN MAKING," "TOOLS FOR MACHINISTS, AND WOODWORKERS," ETC., ETC.

ASSISTED BY A CORPS OF PRACTICAL MEN, EACH A SPECIALIST IN THE SUBJECT OF WHICH HE WRITES.

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The Encyclopædia

OF

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Opening Die-Heads. — When cutting screws on the capstan lathes and automatics, the waste of time caused by having to run the dies off the work after screwing can be avoided by employing opening heads, fitted with chasers which recede from the work at a certain point, inwards or outwards. In their working state they stand as seen, and are kept closed by a catch E, seen in the face view. As a screw is cut, the turret stops in its travel and checks the shank A; but the portion B has a little freedom endwise, sliding over a sleeve screwed into A, the sleeve being encircled with a spring. As B draws away from A, the catch E is released and the ring C turns quickly under the influence of

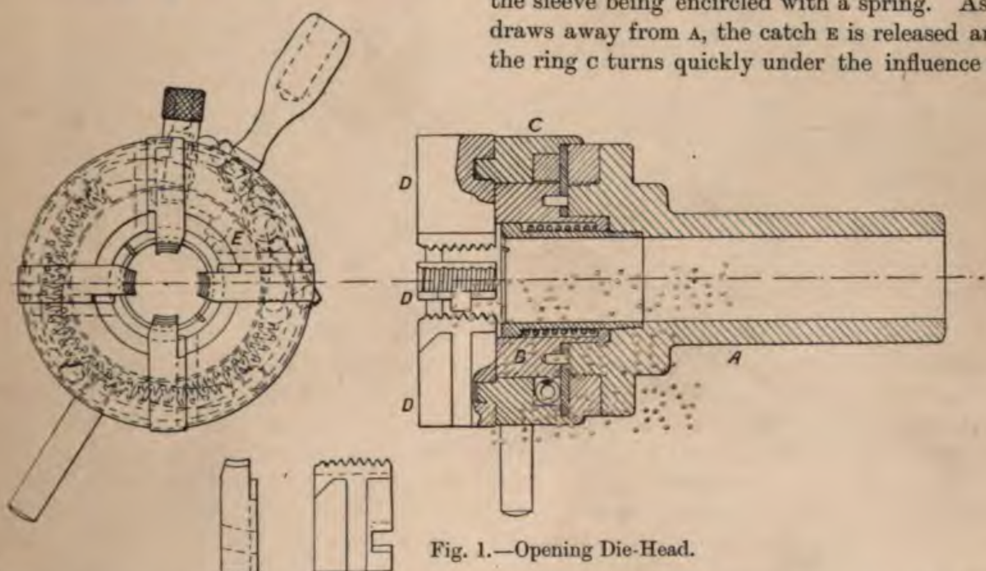

Fig. 1.—Opening Die-Head.

a spiral spring fitted in a groove (see the front view), throwing the chasers off the thread. There is an arrangement at the back of the head, indicated in the face view, for altering the size which the chasers will cut, by means of a couple of screws, so that variations may be made in the diameters of the work. If desired, the die may be opened by the handle at the top, while enabling the head to be instantly drawn back. One of the commonest types in use, by the Geometric Tool Company, is shown in front view and in section by Fig. 1. There is a shank A held in the turret, and a body B, on which fits a cam ring C, holding the chasers D by cam grooves at their rear. It will be obvious that if C is revolved, the chasers must be moved

the other, screwed in at the bottom serves to close automatically, by its contact with a strip fastened to the edge of the turret slide.

Open Joint.—A form of joint of much value in pattern work, employed to secure permanence of form. The edges of boards in broad patterns are kept apart by from $\frac{1}{16}$ to $\frac{1}{8}$ in., with the result that the boards may expand in the damp sand without warping, or making the pattern as a whole wider. The boards are retained flush with dowells, and secured with battens, flanges, ribs, or other portions of the patterns. Examples are broad engine and pump beds, and plated centres of wheels.

Open Mouthed.—Signifies the gullet or gap form of opening in a punching or shearing machine, or hammer, or press, as distinguished from the arch, or close mouth form, which limits the width of work that can be introduced.

Open Rods.—When the full of eccentric sheaves lies between the crank axle and the link, then, if the eccentric rods are open, the above term applies. If they cross each other in that position of the sheaves, the term *crossed rods* is applied. The open rod arrangement is more favourable to equality of lead at each end of the stroke.

Open Sand Moulding.—Making moulds to be poured without a top box. It is only adopted for the roughest kind of work, because the top faces of the castings are rough and uneven. It is generally reserved for the appliances of the foundry, as core plates, loam plates, moulding boxes, back plates; and in outside work, for kentledge, or balance weights, sometimes for fire-bars. As the only time saved is that of the ramming of a top, the economy of open sand moulding is not great. The moulding is done by the method of bedding in, or in many cases by the use of strickles and sweeps. But venting of a bottom bed is not necessary, because the gases get away through the open surface of the metal. It is necessary, however, to make the moulds deeper by from $\frac{1}{4}$ in. to 1 in. than the castings are required, and to provide flow-off channels at the height corresponding with the depth, or thickness of the casting. The metal flows away when that depth is reached. Without this it would not be easy to regulate the exact amount of metal to be poured, and if it were to overflow all round the edges, the removal of the fin would be troublesome. As there is no top, it is necessary to hold down isolated cods of sand with weights, otherwise the upward pressure of the metal would detach them. Thus in a moulding box, every mass of sand between the bar spaces must be weighted.

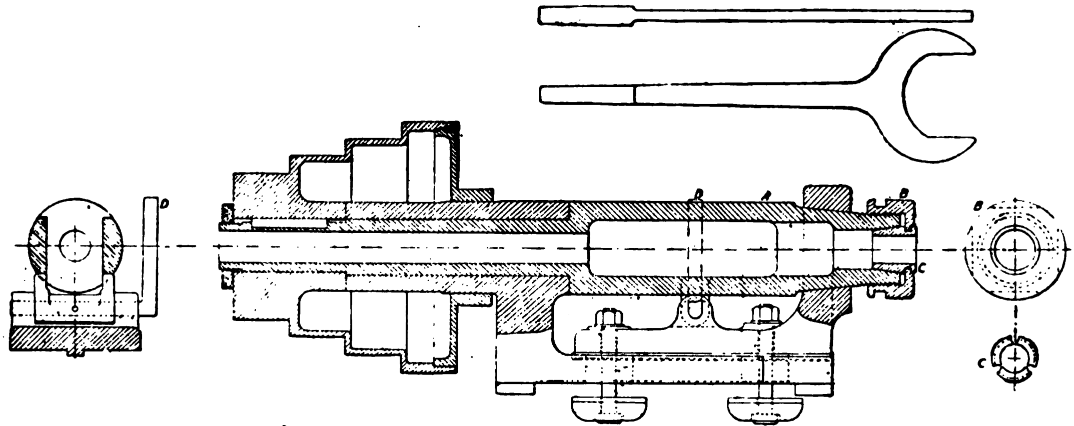

Fig. 3.—Open Spindle Headstock.

Open-Spindle Capstan Lathe.—The distinguishing feature of this lathe is the work spindle, which is cut through to form a clear opening, in which the operator can place his hand to manipulate the bar which is being turned, and which also receives the heads of bolts and pins that are being turned at their ends. Fig. 2, Plate I., shows a lathe of

this class, and the drawings, Figs. 3 and 4, some details. The section of the headstock, Fig. 3, shows the spindle A, with its nose fitted with a screwed nut B, which is tightened up with the large spanner shown, and forces a set of three tapered grips C into the nose, so closing them around the bar. While the spanner is being used, the spindle is locked by turning the handle D seen at the centre, causing a stopper to rise and jam the spindle.

The capstan rest is seen in Fig. 4. It is locked in any of its five positions by a handle engaging in taper notches at the base. The cross-feed of the slide is given by hand, and the longitudinal sliding motion is effected by hand, or by self-acting feed, from the spindle to Lang's handle feed motion in front of the bed, to the feed-shaft, thence through worm gearing to the rack pinion. The feed is put in by tightening the wing nut on the front of the disc, which binds it to the other disc mounted on the sleeve of the worm wheel. A screw-cutting die-head mounted on the rear of the capstan saddle can be brought into use when required, by pulling it over into line with the work. The rest in Fig. 2 is of different type to that in Fig. 4.

Order Numbers.—Numbers stamped in rotation on drawings, patterns, castings, forgings, plated work, &c., to which the time and materials are charged, and by which the numerous jobs are individualised. Time is saved in clerical work, and a record is kept thereby of all jobs. When numbers become unwieldy, say over 1,000, or 10,000, they begin again, and each batch is prefixed by a letter A, B, C, &c. Patterns, core boxes, templets and jigs are stamped with these numbers, and they are used in the office books, or on cards.

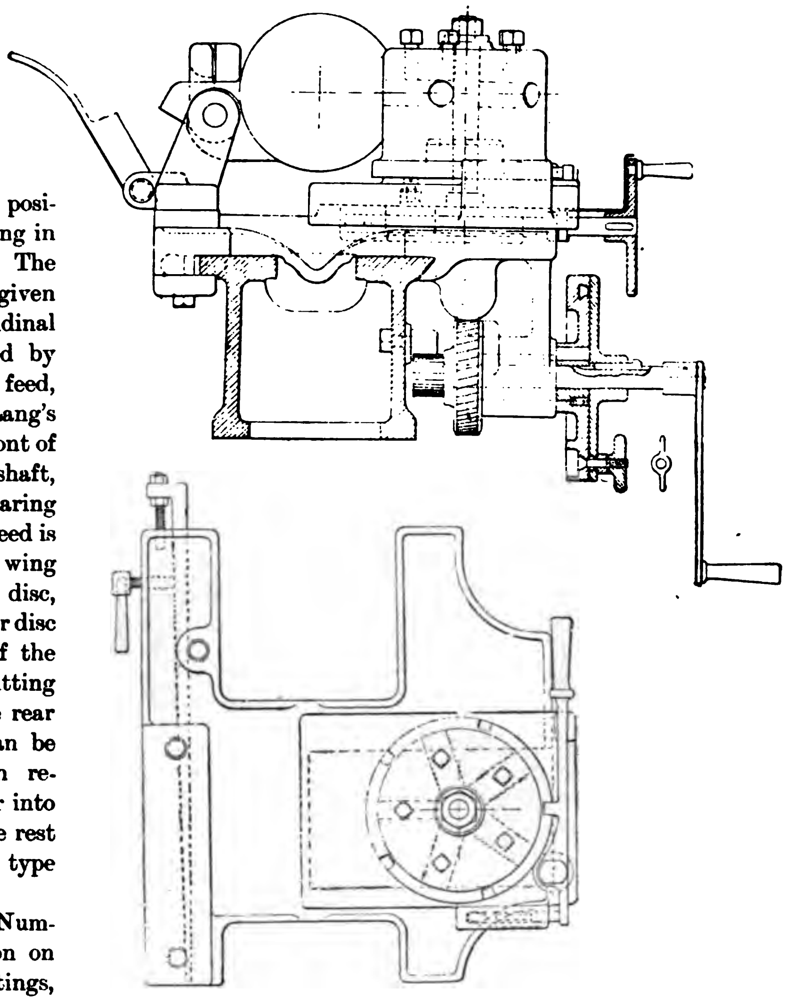

Fig. 4.—Capstan Rest.

Ordinate.—An ordinate is a line of reference which partly determines the position of a point. Thus in Fig. 5, AB, CD are two axes cutting each other at right angles; if any point P be taken, its position is located if we know the distances P*a*, P*b* in the same (as points on the map are referred to by means of lines of latitude and longitude). P*b* is called the ordinate of the point P; O*b*, the abscissa; and P*b*, O*b* are called co-ordinates.

Ores are mineral substances containing metals. The metals are chemically combined

with one or several non-metallic elements, so that their true character may be completely disguised. The chief chemical elements with which they combine are oxygen to form oxides, sulphur to form sulphides, chlorine to form chlorides; and with sulphuric, carbonic, phosphoric, silicic acids, &c., to form sulphates, car-

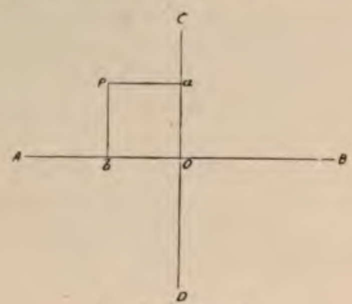

Fig. 5.—Ordinate.

bonates, phosphates, and silicates. The metals are freed from combination with these substances by roasting, smelting, or other processes. Some of the worthless portions of this mass, called the *gangue*, *matrix*, *veinstuff*, or *veinrock*, may be separated by purely mechanical means.

Ores occur in all classes of rock in the earth's crust; in igneous rocks which were once in a molten state, in sedimentary rocks formed by the deposition of material by water, and in metamorphic rocks, which, originally laid down by the action of water have been changed by the action of fire, pressure, or chemical agency. Some ores, as well as native metals are found as alluvial deposits which have been brought down from higher grounds through the agency of water and deposited in the river valleys. In the case of gold such deposits are called *placers*.

In addition to alluvial deposits, ores occur in veins, beds, or masses. A vein or lode is a deposit filling a more or less vertical fissure or crack in the ground. These are found oftener in the older stratified formations, but some occur in tertiary rocks. One theory of the formation of veins is that the metal in the adjoining rock masses became dissolved out by percolating water, and deposited in the fissure; another theory claims that the ore was deposited from hot mineral water ascending through fissures. Radium was discovered in such deposits from the hot mineral water of Bath by the Hon. R. J. Strutt, son of Lord Rayleigh. The extent and dimensions of veins vary very widely. A *gash vein*, as it is called, goes but a short depth into the ground, and extends no very great distance longitudinally. The Comstock lode has been traced to a depth of 3,000 feet, and the famous Mother Lode of California has been followed for a distance of seventy miles. Its thickness may be but a very few inches, or over one hundred feet, the thickness being always taken across the vein at right angles to the walls. The walls of a vein are distinguished as the *hanging wall*—the upper one, and the *foot wall*—the lower one. The walls are sometimes lined with clay, technically called *gouge*, *selvage*, or *flucan*. The rocks in which the vein occurs are designated as the *country*, or *country rock*. The *outcrop* (or *apex* in U.S.A.) is that part of the deposit exposed at the surface. The *dip* is the inclination downwards from the horizontal, and the *strike* the direction the vein takes across country. Veins vary in productiveness, and these varying degrees of richness are denoted by many terms as *course*, *bunch*, *pipe*, *bonanza*, *leader*, *shoot* or *chute*, *pocket*, *chimney*.

A *stockwork* is a mass of rock permeated with an enormous number of very minute veins. Tin ore is mined from such deposits in some districts of Cornwall. Most of these and other terms relating to ore deposits originated in Cornwall where the mining industry has flourished since the days of the Phœnicians. Most of the metals occur in veins.

A *bed* or *seam* is a sheet-like layer of ore interposed between rocks of sedimentary origin. As in the case of veins, a bed may vary considerably in length, breadth, and thickness, but varies less in regularity of composition, length, breadth, &c., than a vein. Its continuity may have been interrupted by igneous agency, or by the bed of an ancient river, resulting in the latter case in what is known as a *washout*, or *dumb fault*. Many of the terms used in the nomenclature of veins apply also to beds. The upper bed is, however, called the *roof*, and the lower one the *floor*. Several of the metals occur in beds.

Masses occur in igneous, sedimentary, and metamorphic rock, and may best be described

as irregular branching cavities in the rock filled with ore. The red hæmatite mined at Ulverstone in Lancashire occurs in masses, and so too does the iron ore in Cumberland.

Details of the ores of the chief metals used in engineering are given below:—

Zinc: Chief Ores.—ZnS, zinc sulphide, blende, sphalerite or black jack, which occurs as a crystalline mineral coloured by the presence of iron and other impurities, and contains, when pure, 67 per cent. zinc and 33 per cent. sulphur. It is frequently found associated with galena: $ZnCO_3$, zinc carbonate, calamine, smithsonite or zinc spar; often associated with dolomite: ZnO, zinc oxide, or red zinc ore. This metal occurs in U.S.A., Germany, Italy, Spain, Belgium, and in small quantities in Great Britain (Wales, Isle of Man, Cumberland).

Copper: Ores.—$CuFeS_2$, or yellow copper ore, a compound of copper, iron, and sulphur; the most commonly occurring ore, containing about 35 per cent. of copper when pure, though this percentage of the metal is not obtained owing to the large proportion of impurities present; Cu_2S, cuprous sulphide, or copper glance; $CuCO_3 + Cu(OH)_2$, green copper carbonate, or malachite, containing when pure nearly 57 per cent. of copper; Cu_2O, red copper ore, ruby copper, or cuprite, containing when pure nearly 90 per cent. of copper; CuO, black copper ore or tenorite. Copper is also frequent in other ores, and occurs native on the southern shores of Lake Superior. Copper ore is mined chiefly in U.S.A., Spain, Mexico, Japan, Australia, Chili, Germany, and to a small extent in the United Kingdom (Cornwall and Wales). Since 1860 the production of this ore in England has steadily and very considerably declined. The ore is chiefly smelted at Swansea.

Iron: Ores.—Fe_2O_3, ferric oxide, or iron sesquioxide, specular iron ore, or red hæmatite, containing up to 70 per cent. of iron; $2Fe_2O_3$, $3H_2O$, ferric oxide combined with water, and termed brown hæmatite or limonite; Fe_3O_4, black oxide of iron, magnetic iron ore, magnetite, or lodestone, a very valuable ore crystallised in octahedra containing 72 per cent. of iron when pure; $FeCO_3$, ferrous carbonate, spathic (spathose or sparry) iron ore, with about 48 per cent. of iron; the latter is found mixed with clay, hence called clay ironstone, and is the source of the greater part of our iron—obtained in the Cleveland district; with coal the same ore is called blackband—obtained in Staffordshire and Lanarkshire; FeS_2, ferric disulphide, largely used in the production of sulphuric acid. Native iron of meteoric origin is also found in masses of varying weight. Iron ore is raised in the following countries in the order given:—U.S.A., Germany, United Kingdom, Spain, France, Russia, Sweden (magnetite at Dannemora, where mines have been worked since the fifteenth century). Until 1890 Great Britain led among pig-iron producing countries, but lost her supremacy to U.S.A. and now occupies the third position.

Nickel: Ore—NiAs, nickel arsenide, or kupfernickel. Occurs also with cobalt in speiss, and in magnetic pyrites.

Tin: Ore.—SnO_2, tin dioxide, stannic oxide, tin stone, or cassiterite, with about 78 per cent. tin when pure. Stream tin is the same ore obtained from alluvial sources. The Phœnicians called our islands the Cassiterides or Tin Islands, this metal having been worked in Cornwall and Devon from remote times. The output of ore in these counties is still greater than that of any European country. The chief sources of tin ore are the Federated Malay States, followed by Bolivia, the Dutch East Indies, Australia, and Great Britain. Metallic tin is not found native anywhere.

Lead: Ores.—PbS, lead sulphide, or galena, of brittle, grey, cubic, crystalline form, and usually accompanied by silver (most of the lead of commerce is obtained from this ore); $PbCO_3$, lead carbonate, or cerusite. Lead is very seldom found in a native state. The chief countries in which ore is mined are:—U.S.A., Spain, Germany, Australia, Mexico, Italy, Great Britain (Cornwall, Derbyshire, and Cumberland).

Bismuth: Ores.—Bi_2S_5, bismuth sulphide or bismuthite; Bi_2O_3, bismuthic oxide or bismuth ochre; it also occurs in a native state. It is mined in Saxony, Cornwall, France, Siberia, Peru.

Antimony: Ore.—Sb_2S_3, antimony trisulphide, antimonious sulphide, or stibnite. Also found

native. It is mined in France, Malay Peninsula, Borneo, and formerly in Britain.

Manganese: Ores.—MnO_2, manganese dioxide, peroxide of manganese, pyrolusite or varvicite; Mn_2O_3, manganic oxide or braunite; $MnCO_3$, manganous carbonate or manganese spar; Mn_3O_4, trimanganic teroxide, or hausmannite; Mn_2O_3,H_2O, manganic hydrate, or manganite. Manganese often accompanies iron.

Ores — Mechanical Treatment of. — *Ore Crushing.*—Metalliferous ores usually consist of somewhat hard rock, and in order that the metals they contain may be extracted from them, they have to be crushed to very fine powder, or sand, as it is called. The ore is brought out of the mine usually in large irregular blocks, looking merely like the blocks of stone one sees on the sea-shore, but if handled, they are found to be very much heavier, and they are crushed by passing the stone through a series of machines, each of which carries the process one step further. The rough stone blocks are first broken by a stone breaker, consisting of a pair of massive jaws, one of which is fixed to the body of the machine, and the other is moved to and fro by power applied in any convenient way. The insides of the jaws are usually lined with removable steel plates, and the blocks of ore are fed to the opening between the jaws at the top, the stone being crushed by the to-and-fro action of the moving jaw, and passing out at the bottom in pieces ranging from ½ in. across up to about 2 in. Fig. 6, Plate I., illustrates a Blake type of stone breaker, made by the Sandycroft Foundry Co., Ltd. It has a jaw opening measuring 24 in. × 12 in., capable of taking a block of 8½ tons in weight. Smaller sizes are also made, down to 10 in. × 8 in. of jaw opening, taking pieces up to 2 tons. There is another form of jaw crusher, arranged to crush the ore to smaller pieces, about the size of a nut, the jaws in this case being smaller, the ore being fed to them from a hopper above, and the space between the jaws at the bottom, through which the crushed material passes, being also smaller. In another form, termed a gyratory crusher, a vertical cone is fitted with wings, or flutes extending radially from it, and revolving within a conical shell containing chilled iron, or steel liners. The ore is fed into the apparatus from the top, and is crushed between the wings of the revolving portion and the liners, passing out at the bottom in pieces of about 2½ in. across. The bottom of the shaft runs in an eccentric bush, so that the cone is given a gyratory motion.

From the stone breakers the pieces of ore are carried to roller crushers, which are of various forms, but all have pairs of rolls fitted with chilled iron or steel sleeves, fixed on cast-iron centres, the rolls being arranged to revolve towards each other, and being held together by powerful springs, and also sometimes protected by housings. The ore is fed to the space between the rollers, and is crushed by them as it passes through, to a certain fineness, usually up to about a 20 to 30 mesh, that is to say, the substance coming from the rolls will pass through a sieve having 20 to 30 spaces to the lineal inch. A fan is also sometimes fixed to the housing enclosing the rolls, by which the fine dust is drawn off.

Grinding Mills.—From the crushing rolls the air passes sometimes to stamps, and sometimes to grinding mills. *See* **Ore Stamps**.

Several forms of grinding mills are employed, as the Huntington, the ball mill, the tube mill, the Griffin mill, and others. In the Huntington and the Griffin mills, and in some other forms, there is a shallow steel trough fixed horizontally, into which the ore to be ground is fed by a hopper, and there are one or more vertical rods, pivoted above, and carrying at their lower ends rollers, which are arranged to run eccentrically on their vertical axes, and to roll on the inside of the vertical portion of the steel trough in which the ore is lying, the action of the steel rollers upon the edge of the trough, grinding the ore to a very fine powder. The ore is supplied to these mills in sizes not larger than ½ in. across, and is gradually ground down till it will pass through a sieve having 2,500 holes per square inch. In the ball and tube mills, there are steel drums or cylinders, divided into sections by hard steel plates, and carrying on the inside a number of hard steel balls. The ore is fed into the drum, and when the latter is revolved, the balls on the inside rub against the steel lining plates, grinding the ore between them and the plates,

Fig. 2.—Open-Spindle Capstan Lathe.
(John Lang & Sons.)

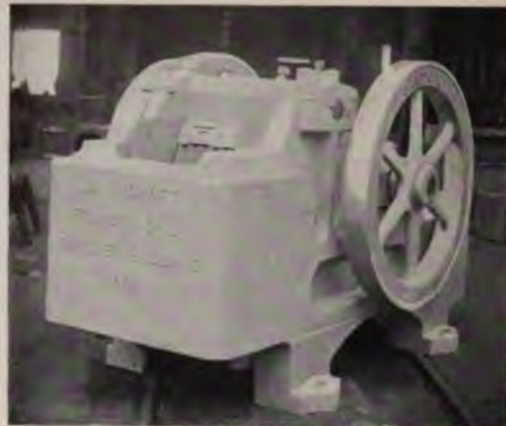

Fig. 6.—Stone Breaker.
(The Sandycroft Foundry Co., Ltd.)

Fig. 7.—Frue Vanner.

Fig. 8.—Tubular Screen.

(Fraser & Chalmers, Ltd.)

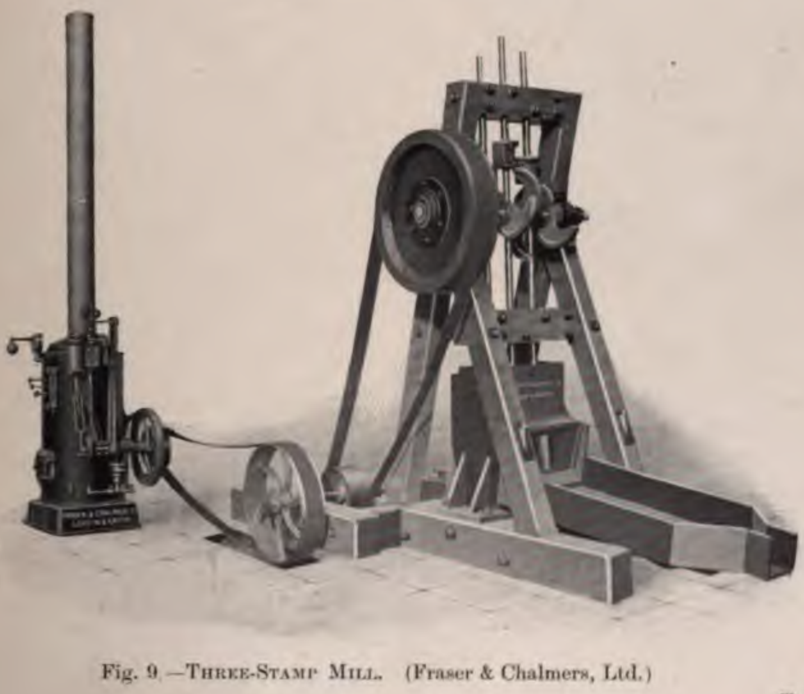

Fig. 9.—Three-Stamp Mill. (Fraser & Chalmers, Ltd.)

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and breaking it up to the size mentioned above.

Ore Mill.—By an ore mill is understood the complete plant for handling the ore as it comes from the mine. The ore is brought from the mine to the mill, usually in trucks running on a tramway, carried overhead on timber or other supports, which should carry it to the level of the top of the mill. If this cannot be arranged, it is run from the mine by a tramway on the level, and is hoisted to the top of the mill. At the top, the trucks containing the ore are first tipped over a "grizzly." The "grizzly" is a screen of iron bars over which the blocks of ore fall in passing to the hopper feeding the stone breaker, while any dust or small material that may be amongst the larger stuff, falls through the bars, and joins the material coming from the stone breaker. The principal portion of the ore goes to the stone breaker, is crushed, and then passes on to the crushing rolls, and thence to the stamp battery, or one of the mills described.

There are two methods of dealing with the ore after it is crushed, known respectively as the wet and dry processes. In the wet process the material is handled wet, water being employed in the process, and after it is crushed to sand, it is carried to amalgamating pans, where the metal is separated by combination with the mercury, and is afterwards recovered by heating the combination and driving off the mercury, as described in connection with amalgamating apparatus. *See* **Amalgamating Pans**. In the dry process the sand is not handled with water, and it is roasted after leaving the stamps or the fine crushing mill. In the process of roasting, it is desulphurised, and sometimes chloridised, the chlorine afterwards being got rid of by the leaching or lixiviation process.

Ore-Concentrating Apparatus.—By concentrating apparatus is meant that which gradually separates the metal, or the salts that are compounds of the metal, from the gangue or waste rock in which the whole is contained in the bed of the mine. As explained, the whole of the rock that is got out of the lode is crushed to very fine powder, and then the powder or sand formed from the waste rock is separated from the metal itself, or the compounds actually containing the metal, these being afterwards treated with heat. The first apparatus employed is called the mixer. The *slimes*, as the sand to which the rock is reduced is called, when deposited in the settling pits into which they flow from the stamps or mills, become very hard, and have again to be broken up and mixed with a certain quantity of water. For this purpose the slimes are fed into a vessel in which are revolving blades, and into which also a stream of water is led. The revolving blades break up the slimes into powder, and the water carries them on to the first screen called a trommel, where all chips of wood, sawdust, odds and ends of wire, nails, &c., are thrown out.

After the mixer there are several forms of apparatus for concentrating the ore. The earliest form is the buddle, used in Cornwall, in which the ore is carried into a circular shallow pit, and four brushes carried on the ends of four arms forming radii of the circle at right angles to each other, sweep over them, water being led into the buddle with the ore, and the gangue and metal being separated mainly by centrifugal action. The buddle has also other forms, as the revolving knife, and so on. Modern apparatus for separating the ore from the gangue in the slimes is more on the lines of what is termed a "vanner." The "vanner" consists, in one form, of an endless rubber belt supported on rollers, so that its upper surface forms an incline, and the ore is delivered on to the surface of the belt at a certain spot that is found by practice to be the best, a stream of water delivering it. The belt is also subjected to a certain cross to-and-fro shaking motion, and there is a row of water jets near the top of the belt. The water which brings the slimes in carries the gangue down to the lower part of the belt, where it is delivered into a receptacle provided for it, while the heavier metal clings to the surface of the belt, and is carried upwards and delivered to a receptacle at the top, the jets of water at the top assisting to free the metal from any minute particles of gangue that have clung to it. Fig. 7, Plate I., shows a Frue Vanner by Fraser & Chalmers, Ltd. The belt is made in either of

two widths, 4 ft., or 6 ft. In another form of concentrator the belt is subjected to an end shake, this being found to answer better with certain forms of ore than the side shake. Other forms of apparatus for concentrating the ore are known as concentrating tables. These are of various forms, one of which consists of a flat surface covered with linoleum, upon which are a series of obstructions, the table being subjected to a movement which varies from the point at which the ore is delivered to the other end. The effect of the motion of the table, the obstructions, and the water with which the slimes are fed on to the table, is to separate the gangue from the ore, to carry the ore upwards to a box prepared for it, and to carry off the gangue to what are called tailings.

Ore Screens.—These are of various forms arranged to separate the ore from the gangue, and to size the rock itself out, as it passes through the different apparatus. Screens may consist merely of a certain number of iron bars, moderately close together, fixed in a frame over which the ore is tipped, and the bars again may be drawn closer and closer together, and may be crossed by other bars till the screen itself becomes a net, and the spaces for the passage of the ore become smaller and smaller; and again the screens may gradually assume the form of an actual gauze net made strong enough to stand the action of the rock, bodies of ore particles passing over them and through them. They are given various forms, as tables, tubular, conical, and so on, while occasionally two screens may be placed one inside the other. In some cases the screens are stationary, the ore passing over them, that portion which is small enough passing through their spaces. In other forms, as the cylindrical, Fig. 8, Plate I., and conical, the screens are given a revolving motion; this, together with the variation of the speed of the ore due to the variation in the diameter of the screen, assists to separate the ore into sizes and to promote the passage of the different sizes through the holes in the screens provided for them. The screens are interposed usually between the different apparatus, as some dust is always made at each process, while smaller portions than that which the machine in front can deal with are also made, and it is economical to sort these out and convey them to their proper machines.

Ore Furnaces.—Furnaces are employed for drying the ore, in some cases previously to further handling, but more frequently for either oxidising or chloridising the ore, the object being to produce either an oxide or a chloride that can be easily dealt with by a subsequent process. Ore furnaces are of three principal forms; the reverberatory furnace, the rotating furnace, and the more modern stationary furnace, of which the Edwards, made by the firm of that name at Ballarat, is largely used all over Australia. The reverberatory furnace is comparatively old, and is well known. There is a broad hearth on which the ore is placed; and a furnace at one end in which fuel is consumed, provides hot gases which pass over the ore and thence to a chimney at the other end of the furnace. Salt is sometimes added to the ore during the process of roasting, and the hot gases carry off the substances that do not enter into combination with the chlorine, and the roasted material is drawn from the furnace through a hole provided for it into a pit below.

There are several forms of rotary furnaces all built on very much the same lines, but with the special arrangements designed by the different inventors. In all of them there is a cylinder built up of steel plates very much like the shell of a Lancashire boiler, but lined for a portion of its length at least, the hottest portion, with fire-bricks. There is a furnace at one end of the cylinder and a chimney at the other, and the cylinder is rotated by means of gearing placed on the outside, and also often carries arms or rabbles, as they are called, for stirring the ore up and carrying it forward. The hot gases from the furnace perform the operation of roasting. The ore enters at the chimney end and is taken out at the furnace end, being subject, it will be noticed, to gradually increasing temperatures. In the Edwards and similar furnaces there is a long chamber with two platforms; and either an endless chain carrying ploughs or other apparatus, generally known as rabbles, move the ore and carry it along the top floor, on to which it is delivered,

to the end where it falls on to the bottom floor, and is brought back again to the point at which it entered, but on the lower floor, and is there discharged. There is a furnace, as in the other cases, supplying hot gases which pass over and through the ore throughout its passage.

Ore Coolers.—Following on the above, which delivers the ore at a temperature of about 1,000° Fahr., it is necessary to cool the ore before it is submitted either to the leaching or cyanide process. In the majority of cases it is cooled by being merely spread out on cooling tables or beds, but machines have also been designed for the purpose, on somewhat similar lines to the rotary roasting furnace. The Argall rotary ore cooler consists of a pair of concentric cylinders, the ore being passed through the inner cylinder, and a stream of water through the annular space separating the two cylinders, the whole being rotated by the same means as the rotary furnace.

Ore Washers.—In the wet process, as explained, the ore is subject to more or less continual washing, separation of the ore from the gangue being carried out largely by the difference in specific gravity. In addition to this, the ore is sometimes passed through a washing "trommel," after leaving the stone breaker. The washing trommel is merely a cylinder with holes of ½ inch diameter or more, according to the class of mineral, and the crushed material from the stone breaker is passed through it, and supplied with a strong stream of clean water, the object being to thoroughly cleanse the ore. The other washing arrangements have been described in connection with the various apparatus.

Ore Picking Plant.— Another very useful apparatus in connection with the handling of ore, is the picking plant. It may consist either of a horizontal table, or of an endless belt. In either case women, who do the picking in those countries where women can be employed for the purpose, stand round the table, and on each side of the belt. The ore is delivered on to the table or the belt, and the pickers, who are more or less skilled, pick out pieces of very good stuff, and pieces of stuff that are practically all waste.

Ore Stamps.—Stamps are usually arranged in a battery, a number of stamps together, according to the quantity of ore to be treated, some of the large mines on the Rand having as many as 200, while very small mines may have only two or three. The stamp is merely a heavy mass of iron or steel, attached to a vertical rod on which a trigger is fixed, the whole being arranged to rise vertically when a cam revolving upon a horizontal shaft engages with the trigger, and to fall when the cam at a later period of its revolution releases the trigger. The stamp head rises and falls inside a mortar box, and the ore which has been brought from the crushing rolls is fed into the mortar box, is crushed by the hammering action of the stamps, and flows over out of the box in the case of gold ores, on to amalgamating plates, the substance being now ground into very fine sand, known as *slimes.* Fig. 9, Plate I., illustrates a 3-stamp mill by Fraser & Chalmers, Ltd., and Fig. 10, Plate II., a 10-stamp mill by the same firm. The latter shows an iron framing, but generally wood is preferable.

Fig. 11, Plate II., is a view in a stamping-house showing the tables which carry the slimes. Fig. 12, Plate II., is Morison's high speed stamp, with Bremner's rapid discharge mortar box. In this, each stamp is lifted by a crank and connecting rod through the medium of a cushioning cylinder reciprocating between vertical guides. When the cylinder ascends, the port is closed rapidly, and the liquid displaced by the relative motion of the moving cylinder and the stationary stamp piston is forced into the air chamber in the latter, until the pressure is sufficient to overcome the inertia of the stamp. The latter then rises with the cylinder, and as the accelerating effort exerted by this diminishes, the air in the piston re-expands and lifts the stamp in relation to the cylinder while they are both moving upwards. The cushioning action is very effective; with an 8-in. cylinder stroke, an 18-in. lift of the stamp is obtained at 126 drops per minute. When the cylinder reaches the top of its stroke the stamp still continues to rise by virtue of its momentum, and by the time it commences to fall, the cylinder has already proceeded a short distance upon its downward stroke. The port being open, and the cylinder

being ahead of the stamp, the latter therefore falls freely under the influence of gravity alone, and when it strikes the ore the shock of impact is not transmitted to the lifting mechanism.

Orthographic Projection.—In the drawing office it is necessary to make accurate representations of mechanisms and parts of mechanisms possessing three dimensions, length, breadth, and height, on a plane surface (a sheet of paper), which has but two dimensions, length and breadth. The difficulty is overcome by making plans and elevations. These are the views which would be obtained if the object were placed above and in front of a horizontal and vertical plane respectively, and the chief points of the object projected on to the plane by straight lines drawn through them perpendicularly to the plane. Much evidently depends on the position of the eye of the observer, just as a shadow of an object thrown by a candle depends on the position of the candle, and in orthographic projection the eye is supposed to be placed at an infinite distance.

Oscillating Cylinder Engine.—A marine type, nearly obsolete, which began to go out when the screw was substituted for paddles in ocean steamers. It was a very excellent engine, preferable to the side lever, trunk, and other forms its rivals, being more compact, with fewer parts and complications. Its rival now in paddle boats is the inclined cylinder type.

In the ordinary oscillating engine the cylinders are low down in the vessel, below the cranks, to which the piston rods are attached directly without connecting rods. Steam enters the cylinders through the outside trunnions on which the cylinders oscillate, so keeping down the temperature of the bearings, and exhausts through the inner trunnions to the condenser, situated between the cylinders, and enclosing the air pump. The valve casings are located against the sides of the cylinder. The valves are operated by eccentrics from the crankshaft, counterbalanced, fitted with slot links for reversal, and connected by suitable levers to the valve spindles. Most oscillating engines have been of simple type, but compounds have also been made. Surface condensers have also taken the place of the old jet condensers. Steam pressures may range from 30, to 80 or 90 lb. Oscillating cylinders are used in **Pneumatic Drills,** &c.

Oscillation, Centre of.—*See* **Centre of Oscillation.**

Osmosis.—*See* **Diffusion.**

Ounce.—In avoirdupois weight an ounce is the sixteenth part of a pound; in troy weight the twelfth part of a pound. In the avoirdupois ounce there are $437\frac{1}{2}$ grains; in the troy ounce 480 grains. 1 oz. troy = 1·09714 oz. avoirdupois. A pint = 20 fluid ounces.

Out of Truth.—A shop term which denotes departure from a level plane or from circular symmetry.

Outside Cylinders. — *See* **Locomotive Engine.**

Outside Lap.—*See* **Lap and Lead.**

Outward Flow Turbine.—*See* **Turbines.**

Oval Chuck.—A compound chuck which is used for turning elliptical shapes, ranging from zero in the major diameter to the maximum range embodied in the chuck. The amount of eccentricity is controlled by a worm and tangent wheel setting a slide to which the worm is attached. Or a ratchet wheel is used. In either case minute subdivisions of the circle permit of finer adjustments in eccentricity than would be afforded by the teeth alone in worm or ratchet wheel. The boss of the tangent screw is subdivided around.

The construction is as follows:—A plate pierced with a longitudinal slot carries a screwed boss by which it is attached to the mandrel nose. A slide moving over the face of this, guided with grooved edges, carries a screwed nose to which the actual chucks holding the work are attached. It also carries the tangent wheel, or the latter is cut round its edge. It slides freely in its grooves and has two horns at the back which pass through the slots in the other plate, and which grip closely the edge of a ring that is attached by a plate with set-screws to the headstock, and which can be adjusted eccentrically in relation to the mandrel without affecting the movement of the chuck, the boss of which passes through a long slot in the ring. The ring being set to any eccentricity, the horns on the front plate which carries the nose for the chucks are coerced by it, and impart an eccentric motion to the work. The

PLATE II.

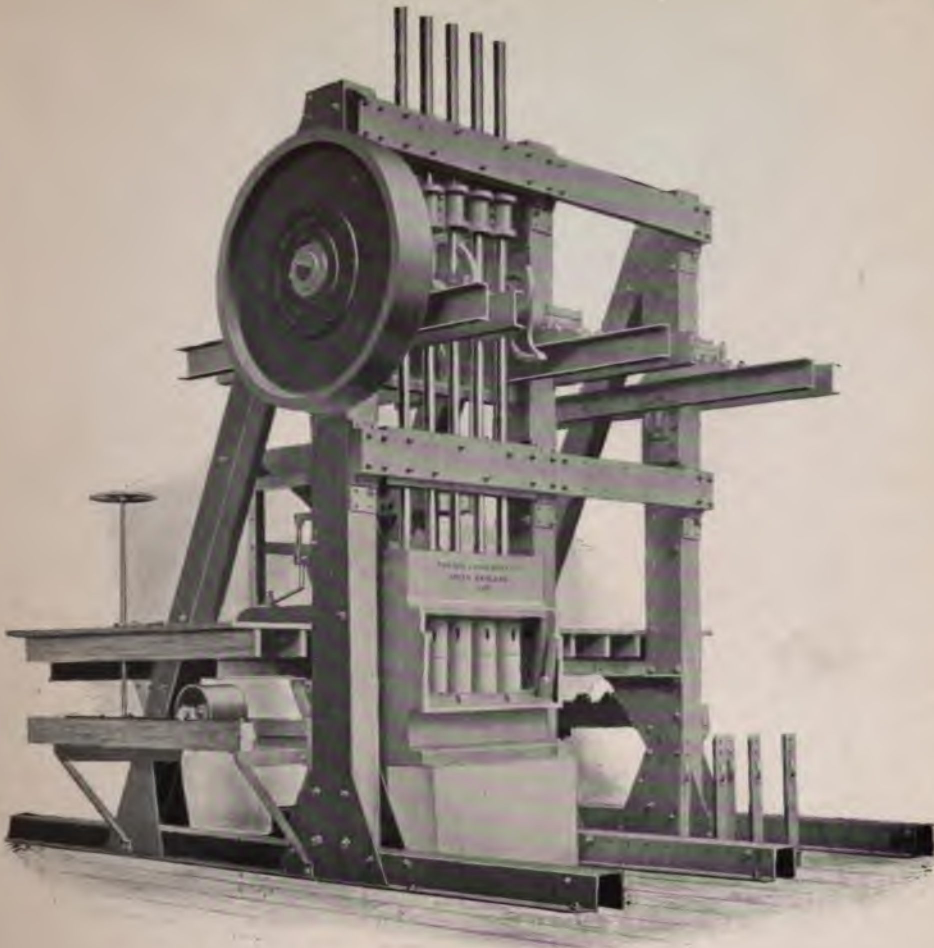


Fig. 10.—Ten-Stamp Mill. (Fraser & Chalmers, Ltd.)

Fig. 11.—View in Stamping House.

Fig. 12.—Morison's High-Speed Stamp.

(The Sandycroft Foundry Co., Ltd.)

To face page 12.

amount of this is twice the eccentricity imparted to the ring.

Oval Hole Cutting.—In the boiler shop these holes are often cut by hand. The ellipse being marked on the plate, holes are punched just within the lines, and in contact, so detaching the central piece of metal. The edges are then smoothed by chipping and filing.

In the larger, better equipped shops, the holes are bored out at once in a machine, with two cutters in an oval cutting apparatus. The principle of this is the same as that of the **Oval Chuck**. Such machines generally include provision for turning end plates and angle iron rings, and boring round holes. The plates are held down on a slotted table, and a standard and overhanging arm carry the mechanism.

Oven Coke.—*See* **Coke Ovens**.

Overall Dimensions.—*Out-and-out* is a synonym of overall, signifying the extreme or sum of all the lesser dimensions on a drawing, or a piece of work. Careful men usually add up the separate dimensions to see if the total corresponds with the one overall dimension, as these are not always found to correspond.

Overblow.—Relates to the final stage in the Bessemer basic process, in which the phosphorus is removed. Also it signifies the continuance of the blast after the carbon has been oxidised in the acid lined converter.

Overhanging Cylinder Engine.—A very popular type in which the obvious feature is the support afforded to the cylinder by its front flange only. Rigidity is ensured by the flange faces and bolts securing the cylinder tightly to the flange of the crosshead guide. The guide is in one with the bed, which is bolted to the foundation. Alignment of the cylinder and the bored guide is secured by checking or registering the flanges together. Thus all the trouble of fitting cylinders and guides to a bed plate is saved. A slight advantage of the overhanging cylinder is that it expands freely with heat, while a cylinder bolted down to a bed cannot do so. The overhanging type is utilised as a wall engine by simply bolting it with its axis vertically.

Overhead Tracks. — These fill an ever extending place in shops. They are used in foundries and light machine shops, chiefly, because more mobile and handy for the lighter classes of work than the overhead travelling cranes. The latter, however, cover the whole floor area, which tracks do not. Overhead tracks generally take the same course as that which would be taken by floor tracks of narrow gauge, but with the advantage of leaving the floor clear. A large amount of varied detail has grown around these in regard to the fittings of the tracks themselves, and also of the conveying machinery, which includes hand, compressed air, and electric driving.

The Track.—Generally this is a single joist section **I**, Fig. 13, suspended from the ceiling, and the wheels of the conveying and hoisting machine run on the inner edges of the bottom flange. This gives the largest amount of head room. Or two joists are arranged parallel, and the wheels run on their top edges. Or, as in the Coburn, Fig. 14, a specially rolled section is used with inner grooves of concave section in which rollers with convex edges run. Single rail tracks are used also, Fig. 15.

I beams are suspended in various ways. They may be bolted directly to timbers, the bolts passing through their top flanges. Or a hanger cotter bolt can be passed through the timber and hold centrally, Fig. 16, a recess being cut in the web to allow the end to clear. Or wrought-iron hangers can be suspended to take the beams. Or castings can be utilised when **I** beams form the floor joists. Another way is to have wrought-iron clips bolted through a beam. If the floor beams are too far apart, or unsuitable to receive the hangers or bolts, a special beam may be carried from the ceiling, or from independent cantilevers coming from a wall adjacent, the beam being continuous. In the Coburn system brackets embrace the tracks, Fig. 14, curving underneath them, leaving room for the carrier between. When single rail tracks are used, made of flat bars set edgewise, then in some cases the trolley wheels run on square edges, as in Fig. 15, in others the edges are convex. The effect of the loading is to keep the trolley wheels perpendicularly. Switches and turntables are fitted in the course of the most complete installations.

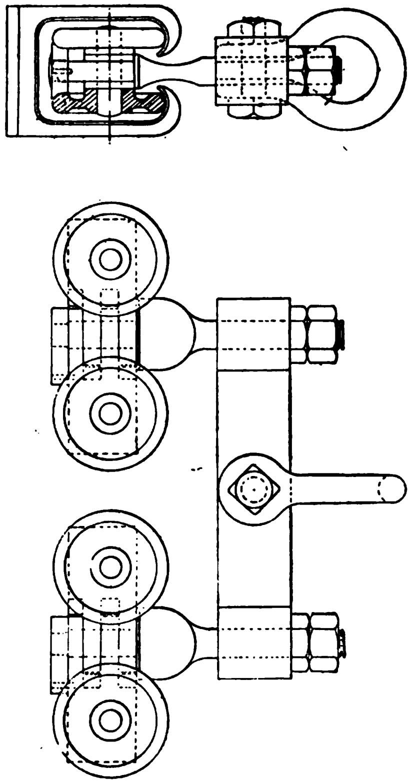


Fig. 14.—Coburn Trolley.

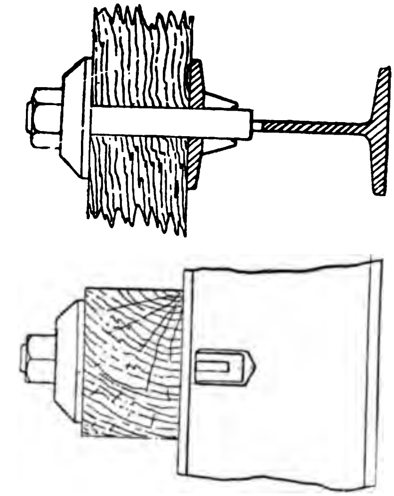


Fig. 16.—Overhead Tracks.

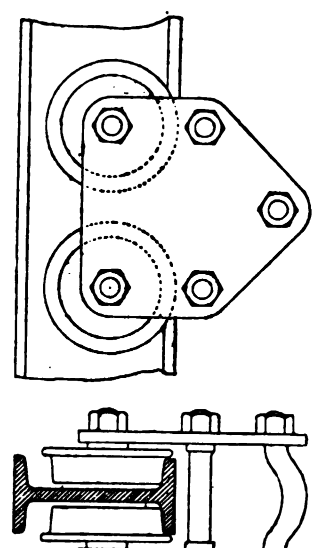


Fig. 13.—Overhead Tracks.

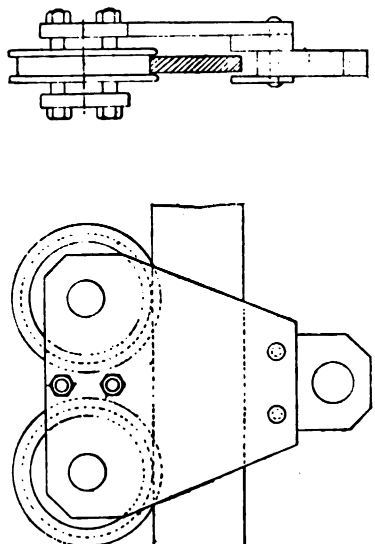


Fig. 15.—Single Rail Track.

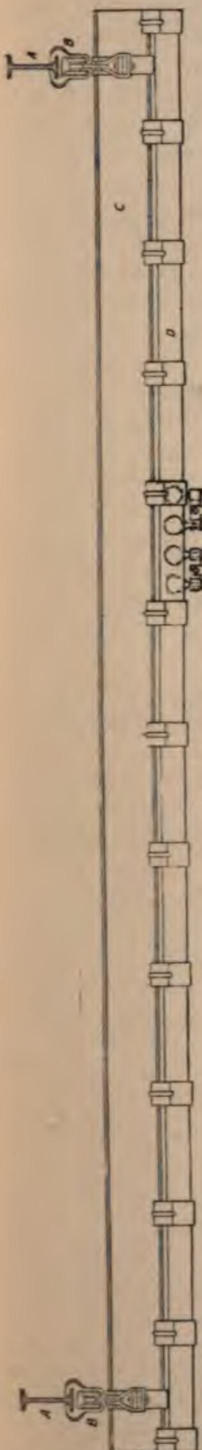


Fig. 17.—Coburn Tracks.

In some cases the track serves the functions of gantries and runways. Thus, Fig. 17, the girders A support a couple of tracks B, and the girder C is a bridge suspended therefrom and running up and down them. Its function is therefore that of a travelling crane, the trolley E being carried by the track D, and traversing across it.

The Trolleys, or Trolley Blocks.—These comprise two large groups—the simple trolleys running along tracks, from which lifting tackle is suspended, Figs. 13, 14, 15, and the combined travelling and hoisting tackle. In the simplest of these a couple of wheels on a single bar track, or four on an I beam track, support the cheeks which carry the eye, or the hook from which the load or the lifting tackle is suspended directly. In the Coburn system these are increased in number with increase in load to be carried. The single carrier with four wheels, two on each side, is used for loads up to half a ton. Double carriers with two such sets of wheels, Fig. 14, are used for higher loads. For 4-ton loads four such sets are employed. The trolley proper is also fitted with knuckle joints when made for running round curves. In the large kinds, frames swivel round their supporting bolts in the manner shown in Fig. 14. *See also* **Pulley Blocks**, and **Telpherage**.

Overhead Travelling Cranes.—Hoisting machines without jibs which travel on runways or gantries above shops and yards, so that no floor area is occupied. No type of hoisting machine has undergone such speedy changes as these have, due to the advent of the electric drive. There is still, however, an extensive field for the utilisation of hand travellers. But self-contained steam travellers and cotton rope travellers are in a dwindling minority. *See* **Cotton Rope Travellers, Electric, Hand, Square Shaft**, and **Steam Travellers**.

Overheating.—This relates specifically to the temperature for working metals and alloys, and to excess of heat in the plates of steam boilers.

Iron and steel suffer by overheating at the forge, becoming partially oxidised, or *burnt*, and lose their nature. Steel is particularly liable to deteriorate from this cause. In the operations of welding, flanging, and bending the temperature must not exceed that which experience has shown to be suitable for those operations. The higher the carbon content the lower must be the temperature for working it. The high temperatures at which iron is worked would ruin any steel.

Overheating of boiler plates has been a fruitful cause of explosions, particularly in the old type of furnace flues before the invention of the Adamson and other seams. When the plates become red-hot, they bulge under the steam pressure, and collapse. The causes of overheating are accumulations of deposit, and incrustation.

Overrunning.—When driving and driven gears run at variable velocities, overrunning will occur. Overrunning is due to variations in the driving force, with corresponding differences in the momentum of the gears. The result is noise, shock, and perhaps fractured teeth. The evils are increased by increase in the amount of clearances. In machine-cut teeth with no clearance they are not apparent.

Oxides.—Are the compounds of oxygen with the other elements. They occur in abundance naturally, and form a very important

class of compounds, many of them being valuable ores. Oxides may be grouped into three classes :—(1) Basic oxides—oxides of the metals possessing the characteristic property of neutralising acids, as seen in the restoration of the blue colour to litmus paper which has been reddened by acid. In combination with water a basic oxide forms a hydrate; all hydrates contain the grouping HO, as in $Ca(HO)_2$, calcium hydrate, $Al_2(HO)_6$, aluminium hydrate. (2) Acid—anhydrides, oxides of the nonmetallic elements, which with water form acids. (3) Peroxides, which readily part with some of their oxygen and so are useful as oxidising agents.

The following oxides are of more or less importance in engineering:—CaO, calcium monoxide (quicklime); MgO, magnesium oxide (magnesia); Al_2O_3, alumina; ZnO, zinc oxide (zinc white); PbO, lead monoxide (litharge); Fe_2O_3, sesquioxide of iron (red hæmatite); Fe_3O_4, ferruso-ferric oxide (magnetite); SnO_2, stannic oxide (tin-stone or cassiterite); Cu_2O, cuprous oxide (cuprite or red copper ore); CuO, cupric oxide (black copper ore).

Oxygen.—O, 16; condenses to a liquid at $-140°$ Cent., under a pressure of 320 atmospheres; sp. gr., 1·108 as gas, 1·124 as liquid; melting point, $-223°$ Cent.; boiling point, $-183°$ Cent. Of all the elements oxygen is the most abundant and important, forming a large proportion of the earth's crust, of the atmosphere, and of water. Some of the most important ores from which the metals of engineering are obtained are oxides of the metals. (*See* **Oxides**.) It is a colourless, tasteless, and odourless gas, whose main characteristic is the great readiness with which it unites with the other elements, fluorine excepted. The rusting of iron is the combination of the metal with the oxygen of the air (forming Fe_2O_3, ferric oxide), and combustion in the furnace is the combination of oxygen with carbon. The removal of oxygen from an ore or other substance is termed "reduction," and the addition of oxygen, "oxidation."

On a small scale oxygen is produced in the laboratory, by heating potassium chlorate, $KClO_3$, with manganese dioxide, MnO_2, but commercially it is obtained in quantity from the atmosphere by Brin's method. Air is pumped under pressure (10 lb. per square inch) over baryta or barium monoxide, BaO, which is heated in retorts to about 700° Cent. The oxygen unites with the monoxide and forms the dioxide, BaO_2. The added oxygen is then recovered by diminishing the pressure while keeping the temperature constant. The collected oxygen is nearly pure, containing only about 7 per cent. of nitrogen.

An intensely hot flame (2,000° Cent.) is produced by burning a mixture of oxygen and hydrogen. The compressed gases are contained in separate iron cylinders, being mixed in a separate chamber to which they pass through regulating valves. The oxy-hydrogen flame melts the most infusible metals, such as platinum. Lime is heated to incandescence by means of this flame, producing an intense light, the oxy-hydrogen limelight.

Oyster Shells.—Sometimes employed for fluxing in the cupola in place of limestones.

P

Packing Case.—A case used for packing machinery for transit and export. It may be an open crate, or an enclosed box, and may or may not be watertight. It is generally made of the cheapest deals, as spruce, or white deal, of from 1 in. to $1\frac{1}{2}$ in. in thickness. The boards forming the sides and ends are held together with battens. Unless a case has to be watertight, the joints abut only. But for long voyages it is necessary to protect all good and bright work by tongueing the joints, and lining the interior with canvas painted with marine glue. In nailing together, the sides are not nailed into the end grain of the ends simply, but partly into battens next the ends. This is necessary to ensure a strong job at the corners. Besides this, hoop-iron bondings are used along all the corner joints. The hoop iron is cut off in suitable lengths, and punched with holes for flat-headed nails. Cases made thus will stand tumbling about with their heavy contents.

Goods are not packed haphazard, or they would become damaged. System is observed by an experienced packer. Cross-bars are inserted, and notched to receive and secure shafting. Blocks are inserted and fastened between adjacent castings or forgings to prevent risk of shifting. Pockets are inserted to receive slight and delicate objects. Bright work, as shaft journals and bearings, is protected with an application of white-lead paint, or of tallow, or boiled oil. If bright surfaces are partly exposed, as in open crates, spun-yarn is wound round over the paint or tallow to prevent risk of contact with other objects.

Packings.—These are of various kinds, the principal being those used for setting or levelling up work, and those for making joints in steam and water joints and connections. *See* **Hydraulic Leathers, Metallic Packings, Pipe Joints.**

Machine Shop Packings.—These are thickness pieces of wood or metal used for levelling up work on machine tables, and for offering resistance to the pressure of bolts and clamps. They are of definite depths, or are adjustable in the form of wedges. The plainest packings are of iron of rectangular section, square, or oblong, from say $\frac{1}{2}$ in., to 2 or 3 in. wide, or deep, and from several inches in length to several feet. They are planed on all faces, so that being used on a level table the truth of the work laid thereon is assured. For the larger packings, lengths of channel, or of beam section are planed on top and bottom faces. Many of the largest packings are open castings, planed on outside faces; some of these measuring a foot or more across the faces. Wedge packings are used to effect slight adjustments in height when the bottom faces of work are rough and uneven. The surface gauge, and the level are used to test parallelism. Wedges of wood are used, but a stock of iron wedges is more permanent. They may be inserted directly between the work and the table, or on the ordinary packings. A pair of reverse wedges is frequent, the mutual adjustment being made use of to raise or lower the work. In one form these are provided with an adjusting screw to slide one wedge over the other, and the edges are graduated to allow of the height of the packing to be read. In some designs the abutting faces are slightly serrated to prevent slip. Packings are also used largely to support clamping plates horizontally, so that the bolts shall have a perpendicular pull. In some cases clamp and packing are combined, and sometimes the bolt forms an integral part of the fitting.

Packings for Steam Pipe.—Until the advent of high pressures, hemp, spun or plaited, was chiefly used for these, and is still retained for low pressures. The hemp is well greased, and wound tightly round the rod, and forced

into the stuffing box with a caulking tool. The screwing down of the gland tightens the packing. As it wears by friction, the gland is still further tightened. Canvas and india-rubber packings have been used extensively in stuffing boxes. These will not stand the temperature of high-pressure steam. They become charred, and shrink, and have to be screwed up; they become hard, the pressure may be excessive, and gritty particles present score the rods. The original packing was water above a piston in the Savery engine, rendered historical by the fact that the leakage of the water past the piston into the steam space below caused rapid condensation of the steam. This gave rise to the idea of the condensation by cold water, first within the cylinder, followed by the condenser separate from the cylinder, by Watt. The real first packings were the old hats of Watt, which were the cause of infinite anxieties.

There are a large number of patent packings into which asbestos enters largely, plaited, or in the form of yarn, with graphite, or metal. Metals cut in thin strips are also used as packings. What are termed sheet packings are used for flanged joints.

Paddle Wheel.—The use of this means of propulsion gradually diminishes, having long since been discarded for ocean steamers in favour of the screw. It is chiefly retained for river, and coasting, and pleasure vessels. Most paddles are of the feathering type. The rigid radial paddles are wasteful, because when they enter the water they enter obliquely, presenting the entire width of their faces, and as they leave they lift a large volume of water. They are only efficient when in the vertical position, because only in that position do they drive the water towards the stern. The slip is taken at from 15 to 30 per cent. One float for every foot of diameter is usually allowed. The area of one float is obtained thus:—

$$\text{Area of one float} = \frac{\text{I.H.P.}}{\text{D}} \times \text{C};$$

D being the effective diameter in feet taken from the centre of opposite floats, C a multiplier, which ranges from 0·25 in tugs to 0·175 in light vessels running at high speeds. The larger the diameter of wheels, the less the obliquity and loss, but considerations of weight and dimensions set limits to size. In the feathering wheels the floats enter and leave the water in nearly a vertical position, irrespective of enlarged dimensions. The floats pivot on pins parallel with the main axis. They are actuated by rods attached to an eccentric strap. This works loosely on a stud—the *feathering stud*, fixed eccentrically on the outer sponson on the side of the vessel. All the rods are attached to the boss, with the exception of the driving rod, which has a rigid connection to the eccentric strap, so driving the strap round the feathering stud.

The great objection to paddle wheels is the unequal immersion of the floats with varying draughts of water. This is but slight in pleasure steamers, but in the old ocean-going paddle steamers, the diminution of coal or cargo would make some feet difference in draught in the course of a voyage.

Painting Machines.—The machines made under the Wallbrook & Wells patents for applying paint to large structures in a spray, from a nozzle, under air pressure. Essentially, a machine comprises a strong tank, which forms the reservoir for the compressed air. Within the tank is the pot of paint, easily removable, and replaced by fresh paint. The air at about 25 lb. pressure, enclosed in the tank, presses on the surface of the paint, driving it through the hose and out of the nozzle. The nozzle has provision for adjustment for speed and fineness.

The speed of painting is from five to six times that obtained by the use of the brush. As the paint dries quickly, a second coat can be applied sooner than in brush work. It shows to great advantage in intricate objects. A saving of 30 per cent. of paint is also made.

Paints. — Protective coatings applied to materials to preserve them from decay caused by chemical action, and to a lesser extent for good appearance. These include other coatings besides those popularly known as paints, as the Barff processes, galvanising, japanning, lacquers, tar, varnishes, &c., described elsewhere. The present article relates to the oil paints. Painting, as it affects the engineer, has to do mainly with cast iron, wrought iron, steel, and timber.

Cast iron is less affected by rust than wrought iron or steel. The reason is that its texture is more homogeneous, and the more so the harder and closer grained it is. Wrought iron is fibrous or laminated, and the layers of scale invite incipient corrosion. Steel, though not laminated, is yet affected by corrosion more seriously than wrought iron. Both wrought iron and steel are often covered with a scale of magnetic oxide, beneath which corrosion may go on unseen.

A paint in order to afford protection from rust must be in actual contact with the metal. This is a vital matter, and explains why an application of boiled oil is, or should be made to castings and plated work before work is done on them in the shops. If they lie about and become rusty, and are painted while in that state, corrosion will go on under the paint. Rubbing the rust off with a scratch brush will not thoroughly clean the surface. The oil may be applied cold, but it is better to warm the work.

The rusting of iron which has commenced previous to the application of paint is as follows:—When red rust, or sesquioxide has formed, the iron beneath it will combine with a portion of the oxygen from the sesquioxide, Fe_2O_3, leaving the latter as a protoxide, or ferrous oxide, FeO, an unstable compound which absorbs oxygen and passes into the higher oxides. As neither of these oxides are stable, the process of corrosion is bound to go on surely though slowly.

The lead paints and the iron oxide paints are both used for iron and steel work. Three coats should be applied, and the first must be allowed to harden before the successive ones are put on. Whichever paint is used, a suitable body is essential. Thus a clear varnish would be of little value for outdoor metal work. A pigment must therefore contain finely triturated solid ingredients held in solution in a medium. Boiled oil is the medium which remains adherent to the iron, and holds the body of oxide of lead or iron.

An essential is that the oxide used shall be a stable one, and not act chemically upon the metal which it is intended to protect.

It seems curious that oxides should be used to protect from oxidation. Lead oxides are more reliable but more expensive than the iron. Lead carbonate, $PbCO_3$, is used principally in the form of white lead, the formula for which is approximately:—$2PbCO_3 + PbH_2O_2$, or lead carbonate and hydroxide. Red-lead paints are used largely in outdoor work. Red lead or red oxide is represented by the formula $2PbO + PbO_2$. Each of these mixes with oil readily, and affords perfect protection. Iron oxide paint is distrusted by many on the ground that it is unstable, and may become a carrier of oxygen to the metal it is designed to protect. But it is often used on the outside of a lead paint. Thus on the Forth Bridge, hot boiled oil was first applied, then two coats of red-lead paint, then two coats of oxide of iron paint. The interior portion of the tubes received one coat of red lead, and two coats of white lead paint, and no iron oxide. 145 square acres of surface had to be painted on this bridge. The material of the old Hammersmith Bridge, protected with white-lead paint, was found as good as new after sixty-two years.

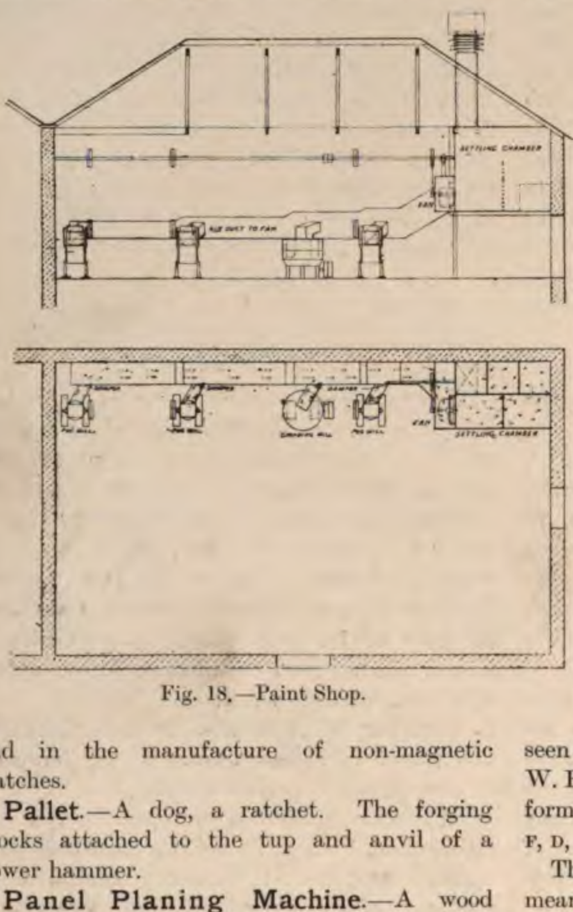
There are good substitutes for white lead as a basis in paints. Griffith's zinc white is a sulphide of zinc, which is an excellent covering pigment, in which property the oxide and carbonate of zinc are deficient. Sulphurous fumes which act on white lead have no effect on the sulphide of zinc. Neither has it any smell. Freeman's non-poisonous white lead is mainly a sulphate of lead, to which oxide of zinc is added. It has good covering property, is durable, and without smell. Oxide of zinc alone is used for white paints. It is deficient in body, and is a bad drier. It is, however, innocuous, and is perfectly white.

Red oxide of lead is preferred by many to red oxide of iron. The red lead is mixed with boiled linseed oil. It is first ground with 10 per cent. of raw linseed oil, the paste resulting is afterwards thinned with the boiled oil. No driers or oil of turpentine are used.

Paint Shop.—Most large engineers' works have their own paint shop, in which the pigments are ground and mixed. As the dust is very injurious, ample ventilation is essential. Fig. 18 shows a typical paint shop. The feature to be noted, besides the general lay

out, is the ventilating arrangements by which the dust is removed. It is effected by the patent fan of F. Hattersley Pickard & Co., of Leeds. Its location is indicated in the three views, and the system of pipes for indraught and discharge.

Palladium.—Pd. 106·5. An element belonging to the platinum group, found in the native state with platinum and gold. It has a remarkable affinity for hydrogen. It is used for certain parts of delicate balances, and in the manufacture of non-magnetic watches.



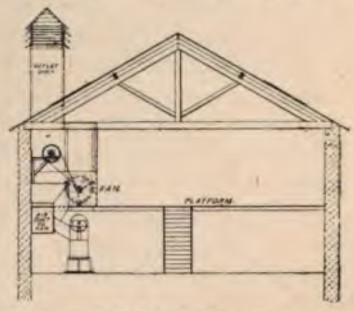


Fig. 18.—Paint Shop.

Pallet.—A dog, a ratchet. The forging blocks attached to the tup and anvil of a power hammer.

Panel Planing Machine.—A wood planer, Fig. 19, Plate III., in which the stuff is fed through by rollers, on a table above which the cutter cylinder revolves. Upper feed rollers grip the surface of the timber also, but these are spring-fitted, to give to inequalities on the surface. The thickness is regulated by raising or lowering the table, and the term *thicknessing machine* is applied generally to this type. The double machines have a cutter cylinder at both top and bottom, so that each face of the timber is planed simultaneously. Another class of planer combines the roller-feed type with the hand-feed or overhand class, an upper table passing the stuff over the cylinder by hand, while rollers beneath feed it through upon a lower table, so that trying-up and thicknessing can both be effected upon the one machine. The wood is kept down "dead" to the table in the panel planers by pressure bars before and behind the cutter block. When the edges of boards or panels are required to be planed or tongued or moulded, supplementary vertical spindles are fitted at the end of the table, to carry cutter blocks which operate upon the edges simultaneously with the planing of the face or faces.

Pantograph.—The value and use of the pantograph have considerably decreased since the introduction of photography, by which enlargements or reductions of drawings in any ratio may much more easily be obtained. An illustration is seen in Fig. 20 of the instrument as made by W. F. Stanley & Co., Ltd. The four tubular arms form a parallelogram with hinged joints at B, E, F, D, so that in any position EB = DF, and BF = ED.

The pantograph is pivoted on a point at A by means of a weight, a pencil is fixed at D′, and a tracing point at J. The instrument moves freely on castors. If then the point D′ be moved over the lines of a drawing, the tracer at J will make an enlarged copy of the drawing, and this will be in the ratio of AD′ to AJ. Conversely, if the point J is run over the lines of a drawing, the point D′ will give a reduced copy. The ratio of reduction or enlargement

Fig. 19.—Panel Planing Machine. (Thos. Robinson & Son, Ltd)

Fig. 26.—Pattern Shop. (British Westinghouse Works, Trafford Park.)

To face page 20.

depends on the ratio AD′ to AJ, and this may be adjusted by sliding these points along their respective rods.

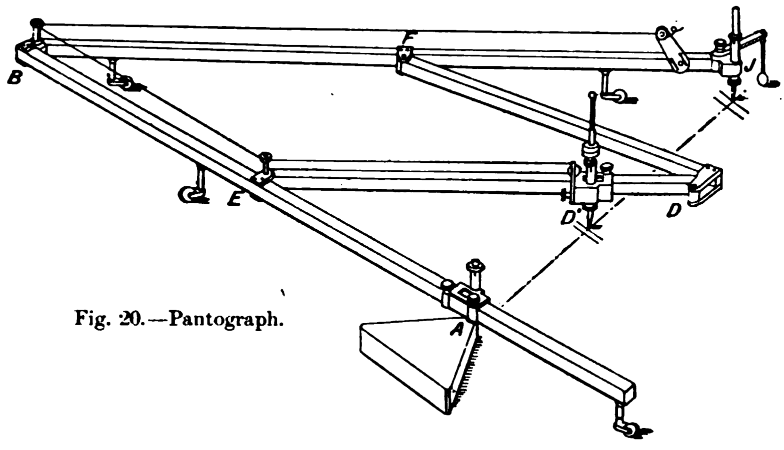
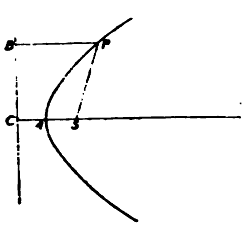


Fig. 20.—Pantograph.

A reliable pantograph costs from five to twenty guineas.

Parabola.—The figure obtained by cutting a **Cone** parallel to one of its sloping sides. The curve of a parabola is such that the distance of any point on it is equidistant from a certain fixed point S, called the focus, and a certain fixed straight line BC, called the directrix. Thus in Fig. 21 PS = PB. The point A is the vertex or apex; the line AS is the principal diameter or axis, and the positions of the focus and directrix are such that CA = SA.



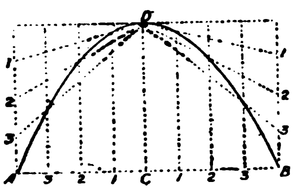


Fig. 21.—The Parabola.

To Construct a Parabola.—Having given the base AB and the height CD, Fig. 21; complete the rectangle as shown by the dotted lines, and divide each half of the base into any number of equal parts, numbering them as shown. Divide the vertical dotted lines into a similar number of equal parts, numbering them also as shown. From the horizontal divisions draw vertical lines, and from the vertical divisions draw lines to D. Where similarly numbered lines cut each other, a point on the parabolic curve is found, and by joining these points the figure is completed. Obviously the greater the number of divisions marked, the greater will be the number of points found.

To Find the Area of a Parabola.—Multiply the axis or height by the base, and take two-thirds of the product.

$$\text{Area} = \frac{2 \times \text{axis} \times \text{base}}{3}.$$

To Find the Length of a Parabolic Curve.

$$\text{Length} = 2 \times \sqrt{(\tfrac{1}{2}\ \text{base}^2) + \frac{4}{3} \times (\text{height}^2)}.$$

The parabolic curve is of particular interest in the study of the path of projectiles. It also provides a curve of great strength and beauty in structural designs.

Parabolic Governor.—A governor, in which the centres and lengths of arms are so proportioned as to cause the balls in their movement to describe a circular arc, which closely approximates to the arc of a parabola. The surface of a body of water whirled round and confined in a vessel is a parabolic curve. The surface is in an artificial condition of equilibrium, and the angular velocity of all the particles is the same. In an isochronous parabolic governor the action is too sensitive. The balls rise too rapidly, and do not fall until the speed of the engine has lessened sufficiently to allow them to fall by gravity. This over-sensitiveness is counteracted by a suitable load, as by a spring which offers an increasing resistance as the balls rise, or by a weight. In the Galloway parabolic governor two cylindrical suspended rollers are substituted for balls, being suspended by links from a crosshead at the top of the spindle. A weight rotating

with the spindle has slots of parabolic form, along which the rollers slide, but which checks the too rapid rise of the rollers.

In designing a parabolic governor the height of the governor must be first settled to suit the particular speed required. A parabola is then drawn with this height for the subnormal, and with its axis coinciding with the axis of the governor spindle. The subnormal is a part of the axis intercepted between any two lines, one of which is perpendicular to the curve, and the other perpendicular to the axis. That part of the parabola is then selected which is most suitable for the swing of the balls, and normals are drawn from thence; where these normals intersect is the centre of the approximate circular arc.

Parallelepiped.—A solid having six faces, each of which is a parallelogram, each opposite pair of faces being equal and parallel. Packing cases, planks, and cubical boxes are parallelepipeds.

To find the volume, multiply the area of one face by the depth of the solid. Since the area of a face is length multiplied by breadth, the formula is:—

$$\text{Volume} = L \times B \times D.$$

Also,

$$\text{Length} = \frac{\text{Volume}}{B \times D}\text{; Breadth} = \frac{\text{Volume}}{L \times D}\text{;}$$

$$\text{Depth} = \frac{\text{Volume}}{L \times B}.$$

In all parallelepipeds the centre of gravity coincides with the centre of weight.

Parallel Files.—*See* **Files.**

Parallel Forces.—*See* **Force.**

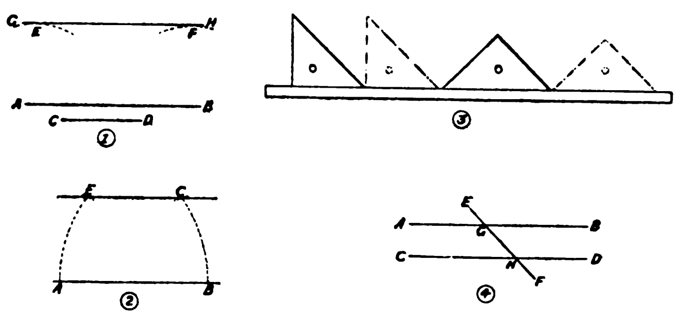


Fig. 22.—Parallel Lines.

Parallel Lines.—Parallel lines are two or more lines so drawn that they are always equidistant from one another, even if produced to infinity.

To draw a line parallel to another, Fig. 22, (1), AB, at a given distance, CD, from it. With centres A and B, and radius CD, describe the arcs E and F, and draw the line GH resting on these arcs.

Through a given point, C (2), to draw a line parallel to a given line, AB. With A as centre, and AC as radius, describe arc CB. With centre B and same radius describe arc AE. With centre A and radius BC, cut AE in E and draw line EC.

Horizontal, vertical, and oblique parallel lines may also be quickly drawn by the use of set squares, the T square, or the straightedge placed at different angles, Fig. 22, (3). The parallel rule, or the rolling parallel are also used for the drawing of parallel lines.

Parallel lines are dealt with in a few propositions in Euclid's first book. The most important of these propositions in its practical bearing is:—"If a straight line fall on two parallel straight lines it makes the alternate angles equal to one another, and the exterior angle equal to the interior and opposite angle on the same side, and also the two interior angles on the same side together equal to two right angles." Thus in Fig. 22, (4) the angle AGH = angle GHD, and angle EGB = angle GHD, and angles BGH, GHD together equal two right angles.

Parallel Motions.—In the early atmospheric, and steam beam engines, the piston and pump rods were connected to the beam by means of chains hanging over the ends, or *arch heads* of the beam. Watt designed the parallel motion to enable the steam to push the beam upwards through a rigid connection. Essentially it consists in a combination of levers by which a right line motion is derived from a circular motion. Though it occurs in several combinations, the principle only need be illustrated by a diagram. Fig. 23, A, B, is one half the beam, rocking about the centre A, C is

the piston or pump rod; DE, DB are connecting links, D rocks about the centre E. Though the ends D and B describe arcs, the effect is that *a* moves in the straight line of the rod C. The diagram shows the mid positions of AB, DE; B and D are located to the right and left of the

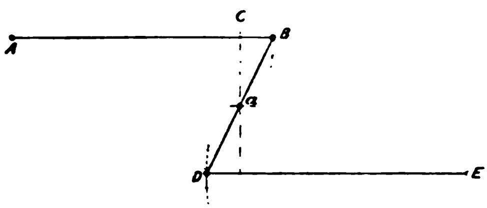


Fig. 23.—Parallel Motion.

rod C to equal distances only at the middle position. This is the condition which has to be fulfilled in designing such a motion. The curve described in the movement is termed a lemniscord, and resembles a much distorted figure 8. The methods of marking out are shown in most text-books.

There are better parallel motions than the Watt, that invented by M. Peaucellier being exact. This, and several others, may be best studied in Professor Kennedy's "Mechanics of Machinery."

Parallel motions of another class, to which the term is more strictly applicable, are those of which the common parallel rule and the Roberval balance are typical. The feathering paddle wheel is essentially a similar mechanism.

Parallelogram.—Is a quadrilateral figure having its opposite sides parallel and equal. The **Square, Rectangle, Rhombus,** and **Rhomboid** are thus the four varieties of parallelograms.

The square and rhombus are parallelograms with all sides equal, the square possessing four right angles. The rectangle and rhomboid have only the opposite sides equal, the rectangle possessing four right angles.

These four figures have certain other properties in common:—(*a.*) The sum of the four angles equals four right angles, or 360°. (*b.*) The area of each figure is found by multiplying together two sides, and the natural sine of the angle included between them. (*c.*) The diagonal divides the parallelogram into two equal parts; so too does any other line drawn from one side to the opposite one and passing through the centre of a diagonal. (*d.*) The two diagonals bisect each other and divide the parallelogram into four equal triangles. (*e.*) The opposite angles are equal, and adjacent angles are together equal to two right angles. (*f.*) The sum of the squares on the four sides is equal to the sum of the squares on the two diagonals. (*g.*) Parallelograms on equal bases and between the same parallels are equal.

Parallelogram of Forces.—*See* **Force.**

Parallel Print.—*See* **Print.**

Parallel Strips.—*See* **Winding Strips.**

Parallel Vice.—*See* **Machine Vice.**

Paring Chisel.—*See* **Chisel.**

Paring Gouge.—*See* **Gouge.**

Parson's White Brass.—An alloy used for lining bearings, and made in various qualities. No. 2 is composed of copper 1 part, tin 68 parts, zinc 30·5 parts, and lead 0·5 part.

Parting.—The joint in a foundry mould. Division is provided for by dusting a layer of parting, or burnt sand in the joint, which being dry and non-adhesive permits of the separation of the mould parts without fracture. Partings may be in one plane, or irregular, as when they have to follow the outlines of patterns of irregular shapes. They are shaped by hand with the trowel, or are rammed on joint boards, or on pattern plates. The second joint may be rammed on the first one of sand, or both joints may be rammed on plates. *See* **Plate Moulding.**

Parting Tool.—A narrow tool used for severing work in the lathe and other machines. Its narrowness is compensated for by much depth, and it is narrower away from the cutting edge than at that locality. It may or may not have a little top rake.

Pass, Passes.—The passage, or the act of passing a plate, bar, or section through rolling mills, producing reduction in area. The grooves are also termed passes, and are open, or closed. An *open* pass signifies that the bodies of the rolls do not touch each other: in a *closed* pass the rolls are fitted with collars and recesses, mutually fitting. In the first-named the material is squeezed out laterally, with the

formation of fin, in the second the opposite condition exists. Rounds and squares are rolled in open passes; flats, channels, rails, and other sections in closed passes.

Pasting.—Sticking halves of cores together with clay wash or core gums.

Paternoster.—A term which has been applied to the chain pump, and to the water-raising chain bucket wheel, or Noria.

Path of Contact.—*See* **Arc of Contact.**

Pattern-making.—For the production of metal castings, patterns or models of some kind are necessary, usually made of wood, and the pattern-maker must know how to construct these. It is necessary to take into consideration not only the best method of constructing a pattern of given form, but the equally important question of how it is to mould; that is, which will be the bottom and which the top in the mould, and where should the mould be most suitably jointed in order to withdraw the pattern. This question of moulding is important because the entire construction of the pattern often depends on it, for only in a few cases can patterns be made precisely like their castings. Thus even in very simple castings it is often necessary to core holes, *see* **Cores**, and **Print**, instead of cutting them in the pattern. In other cases patterns have to be jointed and dowelled loosely in two or more separate parts to facilitate or make withdrawal from the sand possible. Fig. 24, A, shows a pipe pattern in halves which, when together, are kept in correct position by dowels. B is an example of a loose boss and rib on a bracket, the latter being moulded downwards in the position shown, and the loose part coming in the top.

In other patterns, projecting pieces occurring in the vertical sides of the mould have to be skewered on loosely with wires, or brads, as in Fig. 24, C, which represents a plummer block with facings wired on. The wires are taken out by the moulder during ramming up, as in D, as soon as there is sufficient sand round the loose piece to keep it in place. The pattern is then withdrawn, leaving the loose pieces behind to be drawn horizontally into the mould, and then lifted out. For this to be possible, the parts left behind must of course always be smaller than the space they have to be withdrawn through. In some cases large pieces may be withdrawn through a smaller space by making them in parts to draw a piece at a time. E is an instance where this method would be adopted if no other way of moulding the pattern was preferred. F shows how a ring wired-on would have to be jointed to enable it to be drawn in at all, even when thin enough to be

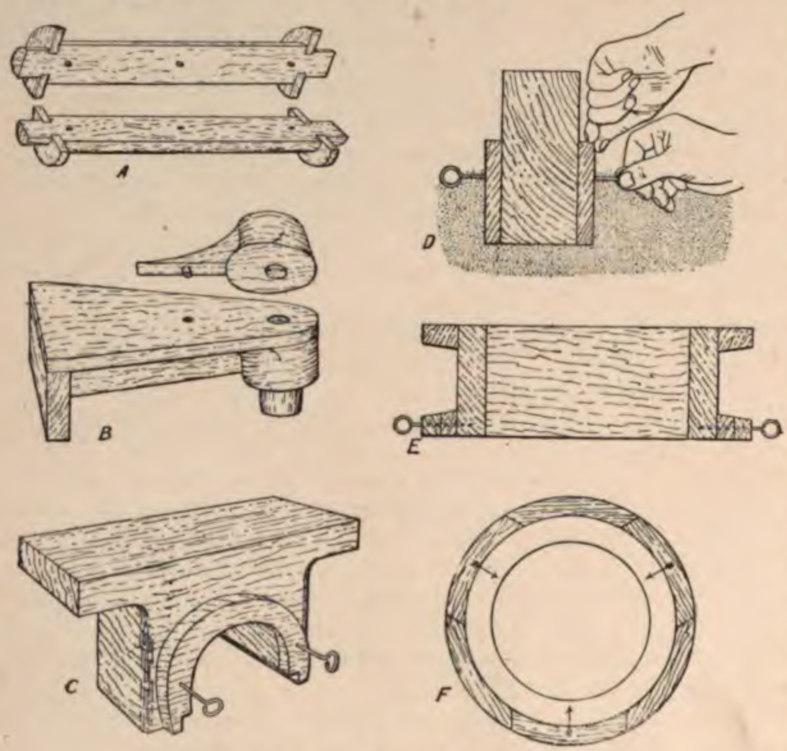
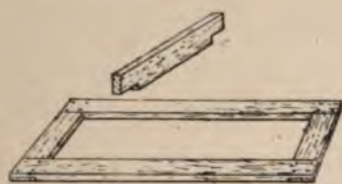
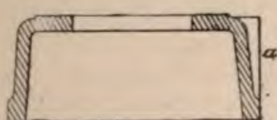
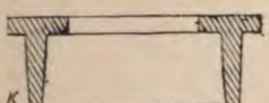


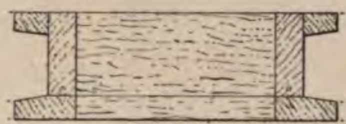
Fig. 24.—Pattern-making.

lifted out. The alternative would be a plane sand joint above the ring, and flush with its top face. Loose pieces are objectionable because of the extra trouble in moulding, and because of their liability to get lost, and therefore another method of moulding is often decided on in preference to employing them to a considerable extent on a pattern. The usual alternatives, if the pattern cannot be moulded in a way that will not require them to be loose, is to put on prints and core out the spaces, or make joints in the mould, and generally in the pattern also, so that when the upper portion is lifted away, the top edges of the projecting parts are left bare and free to draw up without tearing up sand. Another way is to employ a **Draw-back.** Fig. 25, G, shows how a down-joint may be made in the mould, avoiding both a loose piece and a jointed pattern, but necessitating a troublesome sand joint. The example is a plummer block like that in Fig. 24, C. L shows a pattern similar to that in Fig. 24, E, but jointed to correspond with a joint in the mould.









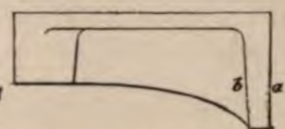


Fig. 25.—Pattern-making.

The pattern-maker generally has to choose between several possible ways of making a mould. In some cases a pattern is not made, but the mould is formed by loam boards. *See* **Loam Moulding**, and **Strickles**. Large plain cylindrical castings are generally made in this way. In others a loam pattern is swept up, and often a considerable number of wood attachments put on it. *See* **Loam Patterns**. In others the mould is made up from cores, which when fitted together form the mould.

In cases where there is repetition of detail, a portion or section of a pattern only is necessary, which is moved from place to place on a bed marked out, and sand rammed round till the mould is complete. In other cases a skeleton pattern is sufficient. A mould for a plate for instance may be formed by a skeleton pattern and strickle as in Fig. 25, H, the strickle being used to level the sand out from the interior, so that when the pattern is withdrawn the mould is the same as if a solid plate pattern had been used.

Castings differ so much from each other that the various possible ways of making any particular one have to be weighed, in order to determine which is the most economical method of producing the mould. The number of castings required is also an important element, for a makeshift method that would be quite satisfactory and best if only one was wanted would not do at all for a great number. Generally when one, or only a few castings of a particular form are required, the principle is to cut down the pattern-work, and go to extra trouble in the foundry; but when a great number are wanted the reverse policy is obviously more economical. In such a case, work is saved in the foundry by providing the moulder with a pattern, or sometimes a number of similar patterns, made in the best possible way to simplify the moulding of castings. And besides this, the patterns must then be constructed and finished to endure long service, a point that is not important when they are not likely to be subjected to much wear.

Small patterns for regular service, especially when of slender proportions, are made of metal,

generally cast from an original wood pattern on which double shrinkage has been allowed. The wood generally used for patterns is yellow pine. When extra endurance is required mahogany is employed, but chiefly for small work. Other woods are occasionally used, but for lightness, freedom from warping, and facility in working, yellow pine is the best that can be obtained cheaply.

Patterns require slight amounts of *taper*, or *draught* in the direction in which they draw from the mould, to enable them to leave the sand without difficulty. In some parts, such as working faces which have to be machined at fixed angles to others, the taper can be only slight, but in other parts more should be given. Thus a bed as in Fig. 25, J, which would be moulded with its top face downwards, must have a great deal of taper given to its sides, by sloping them so that the sand could be lifted out of the inner part, and the pattern would easily draw from the outer sand. But if a vertical face was required at *a*, only a very slight amount of taper could be allowed there, or else a great and unequal amount of machining would be necessary to make it vertical. In a case like K, where the taper involves thinning down the section of the sides, it is seldom possible to give as much taper as in cases like J, but when the sides are shallow, or in castings such as fire-bars, where the taper is required in the casting, the section may be made much thinner at bottom than at top. In many, as in the foot of a bracket like M, one side *a* of the tapered part is a working face, which must be kept as nearly as possible square, while a considerable amount of taper can be allowed on the other side *b*. More taper is necessary on interior faces which enclose sand than on outer ones. Thus in a case like K more taper would be allowed on the inside than on the outside. *See* **Alterations to Patterns, Bevel Gears—Patterns for, Boxing up, Column Making, Core Box, Fillets, Gears, Half-Lap Joint, Lagging up,** &c. &c.

Pattern Registration.—A proper registration of patterns, to facilitate references, and entries, a system of order numbers, and a good method of charging out and storing castings stand in intimate relation to each other. The neglect of these matters causes inevitable confusion, loss of time, and frequently loss of pattern parts, and the going astray of castings even in a foundry where only a few tons of castings are made in a day, while such evils are magnified with increase of output.

The patterns in a works of moderate size only, which has been in existence for but a few years, will number some tens of thousands. A large proportion of these are constructed with several pieces detachable from the main body of the pattern, besides which most patterns have satellites in the form of core boxes, often ranging in number from one to a dozen. Unless each pattern, therefore, and every one of its loose details is registered, frequent losses are inevitable between the pattern shop, pattern stores, and the foundry. Each pattern, with all its loose parts should be stamped with a reference number, entered also in a registration book, or on a card in some systems, and by which it can be identified now or years hence. Then there are the "order numbers" or numbers by which office orders are issued to all the departments of a works, and these are used in conjunction with pattern numbers; *e.g.*, Order number B. 480. Pattern number C. 8406. Numbers required off, 50. The same numbers are used for charging out and storing the castings by. So many castings to such an order number, from such and such pattern numbers. And so these numbers go right through the shops, and time and materials, charges, &c., go back into the office in connection with these numbers.

Pattern Shop.—A pattern shop (*see* Fig. 26, Plate III., and Fig. 27, Plate IV.) may be either a department of an engineering firm, or it may be an independent shop taking orders from firms which find it more convenient to put out some or all of their pattern work. Pattern shops vary considerably in size and equipment. There are rather fewer machines employed in pattern-making than in most other trades, because patterns vary so greatly that beyond sawing and planing there is not much that machines can do to assist the pattern-maker. Lathes are necessary, and in this

Fig. 27.—Pattern Shop. (Marshall, Sons, & Co., Ltd., Gainsborough.)

Fig. 31.—Pendulum Saw. (Thos. Robinson & Son, Ltd.)

Fig. 38.—78 B.H.P. Petrol Engine. (John I. Thornycroft & Co., Ltd.)

To face page 26.

respect the equipment of the pattern shop differs from that of the carpenters', joiners', and other wood-working shops, except of course that of the wood turner, who works exclusively at the lathe.

The shop must be provided with wood-workers' benches, means of heating glue, sawstools, and trestles, long straightedges, large drawing boards of various sizes, a large assortment of screws and wire nails, shooting and angle boards, glass-paper, shellac varnish, and numerous other trifles, apart from the machinery. The ordinary bench tools are generally owned by the pattern-makers themselves, but a considerable number of shop tools are desirable, such as handscrews, long rules, and large trammels. With the exception of benches and handscrews the wood articles mentioned are generally made in the shop. A grindstone or emery wheel is required for grinding tools.

There should be at least two lathes, one for large, and one for medium and small work. In most shops not less than three are advisable, because such a quantity of turned work of medium size is required that men are sometimes delayed through having to wait for the use of a lathe. This, however, depends on the number of men employed. Wood-workers' lathes provided with fork centres, face plates, and cup chucks, are required, and, of course, should be driven by power.

If only one machine saw is installed it should be a **Band Saw,** but a **Circular Saw Bench** is extremely useful and desirable. If the number of men employed justifies it, more than one of each of these machines should be installed. The circular should have separate saws for ripping and for cross-cutting. If large and heavy work is done, a cross-cut circular on a swing arm is useful for cutting to length. The saws require sharpening every few days, and it should be someone's duty to attend to this and see that they are in good working order.

Planing machines come next in importance to saws. They save a great deal of time and laborious work. They are used both for surfacing, or jointing, as it is called, and for planing to thickness. Some are intended to perform only one of these operations, while others will do both.

The trimmer is a very useful machine for squaring ends; more useful perhaps in the pattern shop than in any other branch of woodwork. There should be one of these within convenient distance of every workman.

Power for driving the machinery may be obtained from an engine in the shop, which may be a gas-driven engine if steam cannot conveniently be conveyed, but in most cases the pattern shop is situated close to others and shafting is brought through the wall. Electric driving may be installed. The pattern shop should be as near the foundry as convenient, and should have a doorway through which the largest work may pass without difficulty.

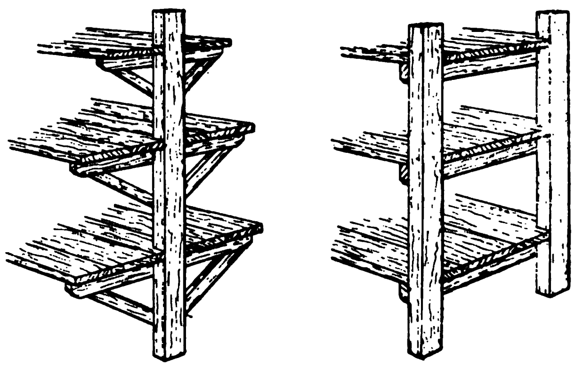


Fig. 28.—Shelves in Pattern Store.

Pattern Stores.—As patterns accumulate rapidly, and it is seldom advisable to take them apart and use the material, it is important that they should be stored so that any pattern required can be readily found. So much space is required for their storage that a separate building is generally necessary. It should, of course, be free from dampness, and be well provided with windows to avoid as much as possible the use of artificial light in looking for patterns. It should also be within easy distance of both foundry and pattern shop. The interior of a pattern stores is fitted with shelves. These extend all round the walls and form avenues across the floor, so that no space is unoccupied except that necessary for walking in. Very large patterns, of course, cannot be stored on shelves but must go on the floor. Columns and

pipes may go in racks similar to those used for timber. If the building is more than one story high the large patterns should be on the ground floor, and shelves may also be provided there for patterns of moderate size, but a considerable amount of floor space must be left clear for storage. Avenues of shelves may be constructed as in Fig. 28. Patterns may be either stored all of a kind together, or a set of patterns for any particular machine stored in a group. Generally both systems are adopted, because most firms make standard machines which are constantly being repeated, while a lot of other work is casual and miscellaneous in character. There is often no objection to altering patterns of the latter class to make them come in for other odd work, and if they are stored so that all bushes, brasses, brackets, &c., are kept together to select from when castings are required, time is saved in searching, and similar patterns are less likely to be made twice over.

When the stock of patterns is very large it is advisable to have some record of what is in the stores, and where things are to be found. This may be done by numbering both shelves and important patterns, and keeping particulars in a book, so that if patterns are put in their proper place when they come from the foundry they may be quickly found when wanted again. *See* **Pattern Registration.**

Pawl, or **Paul**.—A device for arresting, or imparting a movement of some kind at a definite stage or stages. It occurs in two forms, one is the detent or ratchet pawl for stopping the rotation of a wheel at positions corresponding with the spacing or pitch of the teeth. The other is the catch pawl, by which the endlong movement of a shaft is checked at a stage which corresponds with the in or out of gear positions of toothed wheels. In the detent type the movement of the ratchet wheel throws the pawl out of engagement by reason of the slope of the teeth. It is compelled to fall into the next tooth by the action of gravity, or more generally by that of a spring which operates in any position of the pawl. Many pawls are double, to act when thrown over to right or left. In such a case the teeth are like ordinary gear wheel teeth instead of the ratchet or sloping type. *See* **Ratchets**.

The shaft pawl falls between collars on the shaft to give the in or out positions of the gears. It is lifted and dropped by hand, and is usually made heavy to ensure its lying in position securely.

Peak Load.—The highest load on a central station.

Pearlite.—A mixture of ferrite and cementite, deriving its name from the colours produced by etching, which resemble those of mother of pearl. It is either lamellar or granulated in appearance. The first exists in steel which is cooled very slowly from a high temperature, and particularly in steel which is not annealed. The pearlite in steel which is annealed at just below Ar_1 is granular.

Pease Meal, or **Pea Flour**.—Used for dusting brass moulds.

Peat.—A fuel of variable utility, ranging from the light brown spongy variety to the heavy pitch-like substance approaching to lignite. The first is that found near the surface, the second at the lowest stratum of boggy ground. The various stages represent stages in the obliteration of the original organic structure of the mosses, which have been changed in the presence of moisture, with partial exclusion of air. Peat may be likened to wood in respect of its organic composition; but, unlike wood, it contains from 5 to 20 per cent. of incombustible matter, chiefly sand. Peat is prepared for use by air drying, in which state it crumbles readily. Methods of compression are in use, by which it is consolidated and its objectionable bulk diminished.

Air-dried peat contains from about 8 to 25 per cent. of water. Its specific gravity varies from 0·1 to 1·0. Its average chemical composition is, carbon, 52 to 66; hydrogen, 4·7 to 7·4; oxygen, 28 to 39; nitrogen, 1·5 to 3 per cent. Its calorific value ranges from 3,000 to 3,500 units. Peat is readily inflammable, and burns with a red smoky flame with a characteristic odour. It yields a large amount of ash. It is used in steam raising and metallurgical processes.

Pedestal.—A plummer block. *See* **Bearings**.

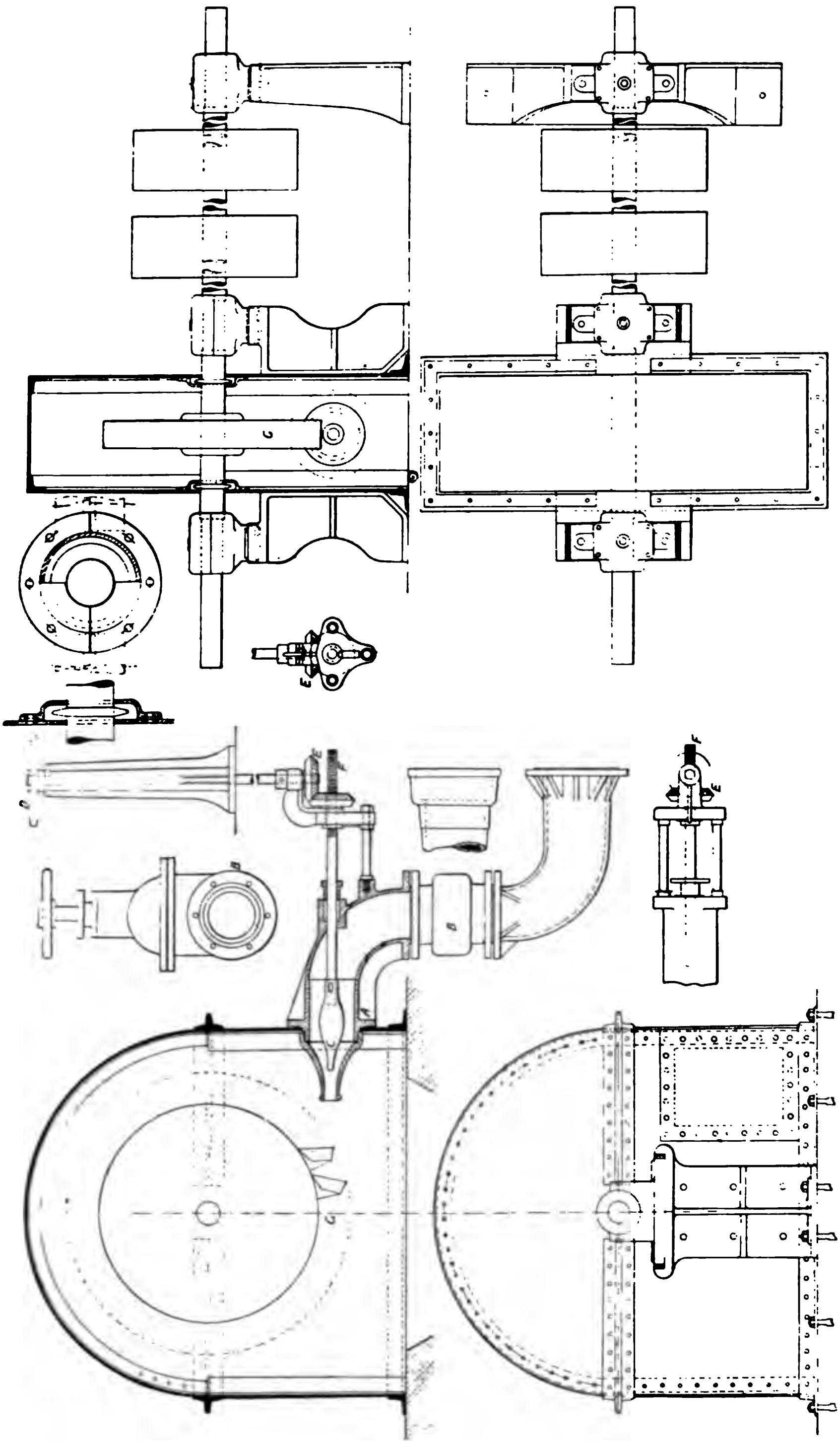


Fig. 29.—Pelton Wheel. (Messrs Carrick & Ritchie.)

Peel.—A long-handled, flat-ended implement used to distribute the half pigs of iron over the hearth of an open-hearth steel furnace, when charged by hand. It is about 11 ft. in length, and the flat end about 8 in. by 5 in.

Peg and **Cup Dowells.**—Dowells of brass comprising a plain pin and plain hole, each being held in place by circular groovings. Being driven into the soft wood, the swelling of the latter fills up the annular grooves and retains the peg and the cup in place.

Pegging Rammer. — *See* **Moulders' Tools.**

Pelton Wheel.—A type of impulse water

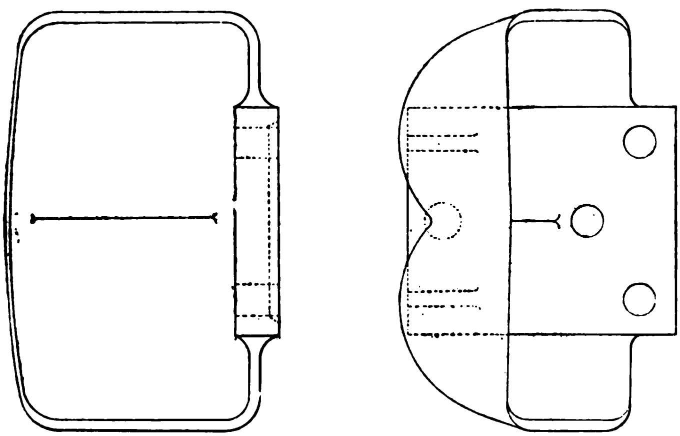
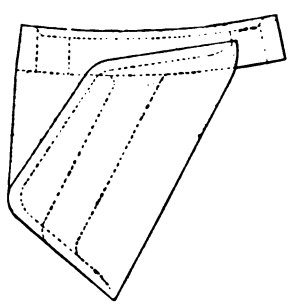


Fig. 30.—Bucket of Pelton Wheel.

motor conveniently classed with the turbines. It is also termed a *jet wheel* and a *hurdygurdy* in the mining districts of America, where its use first became established. Its efficiency is very high, being as much as 80 per cent. It comprises a set of double buckets arranged round the periphery of a wheel, and driven by water issuing from a nozzle, under



pressure due to head, or to that artificially produced, as in the high-pressure systems of towns. The water strikes the buckets normally to their faces, or at 90°. The buckets being double, the water strikes the ridge formed by the meeting of the buckets, and is carried round some distance before it escapes. The simplicity of the wheel, apart from its efficiency, explains its growing popularity. In districts where sand and grit are mixed with water the cutting action on turbine blades is serious. The buckets of the Pelton wheel can be readily replaced. The framing is also very simple, being either of wood or iron. The nozzles used may be single or double, capable of regulation, or not. The single nozzle is the more common. But if the speed of the wheel with a single jet is insufficient to give the power required, two jets will give nearly twice the power of a single jet for the same size of wheel. Another method is to place two or three single jet wheels side by side on the same shaft.

As the power from a given size of wheel is increased by increasing the volume of water made to impinge on the buckets, this is taken advantage of for regulation. Two or three nozzle tips of different sizes are made to interchange on the same wheel to suit variations in water supply. The supply may be regulated roughly at the stop-valve, but a better plan is to have a spear rod, which is pushed into or drawn back out of the nozzle tip. A more precise and automatic arrangement is by governing, by which the area of discharge is increased or diminished.

Fig. 29 illustrates a Pelton wheel of 3 ft. diameter, by Messrs Carrick & Ritchie. The casing is made of steel plates and angles. The upper part of the casing is removable. A door is provided in the side to give access to the nozzle for the purpose of changing it. The nozzle casting A is bolted to the end plate, which is therefore made thicker than the other plates. A sluice-valve B is fitted to the nozzle casting. The nozzle is of the regulating type, the spear rod C being moved inwards or outwards by the hand-wheel D, operating the bevel gears E, and screw F on the spear rod, as shown. The wheel, outlined at G, is carried on a steel

shaft with three self-oiling bearings. Two of the standards are fixed immediately outside the casing, the third at a little distance away to allow room for the driven pulleys. The pulleys are of a size suitable for transmitting the power of the wheel at a speed of 3,000 ft. per minute. A drawing of a bucket to a larger scale is shown in Fig. 30.

Pendulum.—The study of the oscillations of a pendulum has attracted scientists and philosophers for many centuries. A weight suspended by a thread has revealed the acceleration due to gravity, the earth's mean density, and supplied a proof of the perpetual rotation of the earth round its axis. In engineering it is also closely connected with the laws governing the pendulum governor.

Experiment with a nut attached to the end of a thread will reveal the following truths:—(*a*) for very short swings, no matter what length of thread be used, the time of each oscillation is practically the same; (*b*), the shorter the thread, the faster the weight swings, and the longer the thread the slower it swings. By experimenting with strings of varying lengths it will be seen that a thread a quarter the length gives twice the number of oscillations in a given time, a thread one-ninth the length gives three times the oscillations, and so on. That is, the number of oscillations varies inversely as the square root of the length of thread.

The relation between the various factors connected with a pendulum is shown in the proportion,—$t^2 : \pi^2 :: l : g$, where t is the time in seconds of one oscillation; π, the ratio of the circumference to the diameter of a circle = 3·1416; l, the length of the pendulum; and g, the acceleration of gravity. From this relation the time of swing may be found,—$t = \pi\sqrt{\frac{l}{g}}$, or g may be calculated,—$g = \frac{l\pi^2}{t^2}$.

In a conical pendulum, in which the weight rotates in a horizontal circle instead of oscillating in a vertical plane, the formula becomes:—$t = 2\pi\sqrt{\frac{h}{g}}$, h being the altitude of the cone. Where the number of revolutions per minute, n, is considered, $n = \frac{30}{\pi}\sqrt{\frac{g}{h}}$.

Pendulum Governor.—The ordinary type of governor, which is based on the swing of the pendulum. *See* **Governors.**

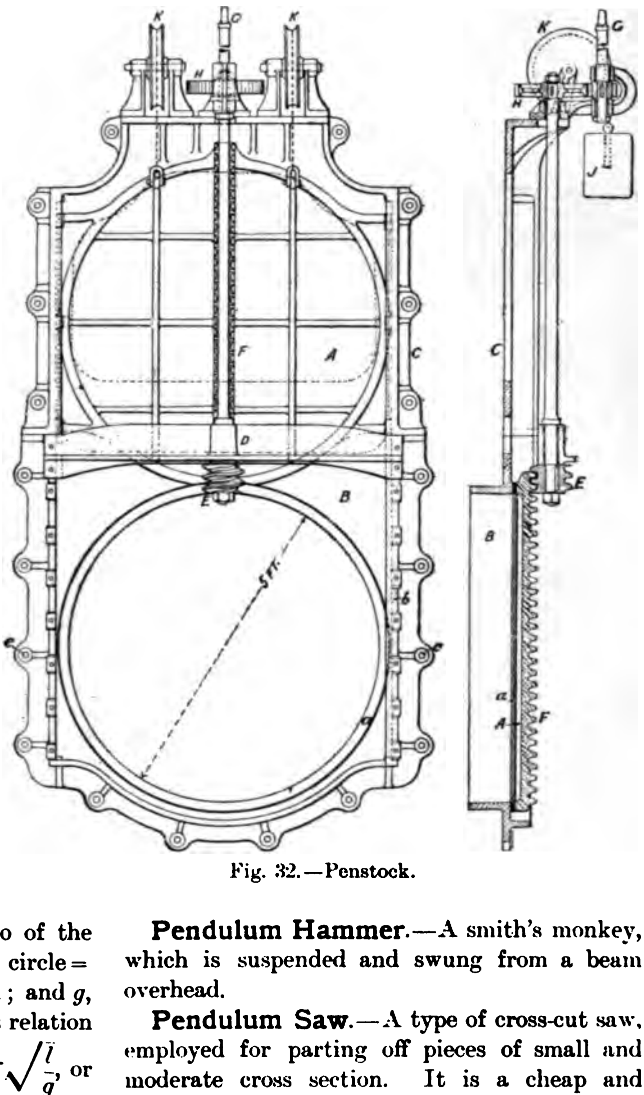


Fig. 32.—Penstock.

Pendulum Hammer.—A smith's monkey, which is suspended and swung from a beam overhead.

Pendulum Saw.—A type of cross-cut saw, employed for parting off pieces of small and moderate cross section. It is a cheap and handy machine, and takes up but little space. Fig. 31, Plate IV., illustrates one of this type. The circular saw is attached to a mandrel running in bearings at the bottom of a suspended

frame, hung on trunnions supported by brackets either on a wall, or upon a ceiling. The driv-

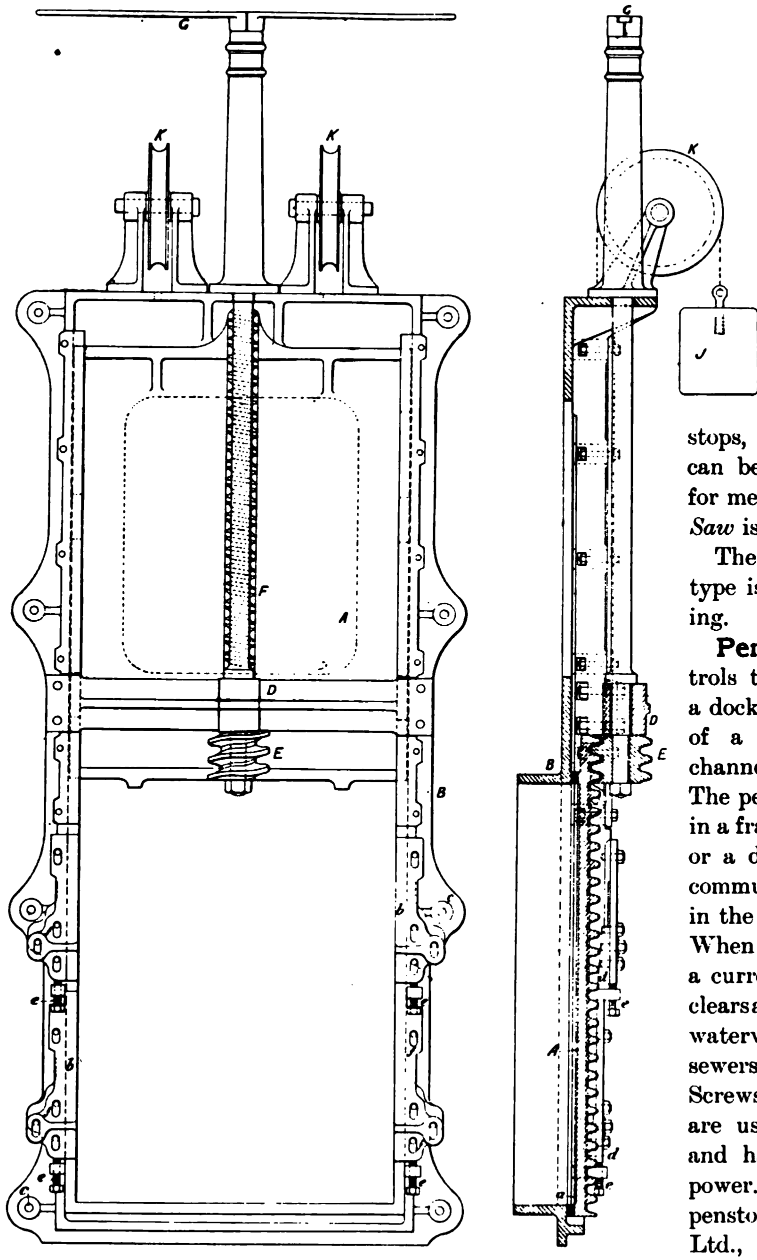


Fig. 33.—Penstock, with Wedge Blocks.

ing pulley is mounted on a shaft within the trunnion bearings, and is belted down to a pulley on the mandrel. Fast and loose pulleys for shipping the belt which comes from the countershaft are placed alongside the top driving pulley. The whole arrangement is hung above a long bench which supports the lengths of timber being sawn, and the saw passes through a slit in the bench when drawn forward by means of a handle fixed in front of the mandrel bearings. A counterweight device returns the swing frame to the rear when the handle is released. The bench is usually provided with a rule, and gauge stops, by which repetition sawing can be done without the necessity for measurement. The name *Swing Saw* is often applied.

The **Hot Iron Saw** of pendulum type is illustrated under that heading.

Penstock.—A gate which controls the discharge of water from a dock sluicing for the maintenance of a fair way in the entrance channel. Also termed a *paddle*. The penstock is of cast iron, sliding in a frame of iron, either in a culvert, or a dock gate. Lifting it effects communication between the water in the dock and the channel outside. When there is a difference in level a current is produced, and its rush clears away mud and deposit from the waterway. The large valves used in sewers are also termed penstocks. Screws, or worms working in racks are used for operating penstocks, and hand, hydraulic, and electric power. Figs. 32 and 33 illustrate penstocks by Glenfield & Kennedy, Ltd., of Kilmarnock. They are operated by worm and spiral rack. In these figures A represents the penstock door, B, C the main framing, in two pieces, in Fig. 32; *a*, *a* gun-metal strips on the working faces. Strips *b* bolted to B confine

the door tightly against the faces of the opening. The girder D carries the bearing for the worm E which operates the spiral rack F. The worm is hand-operated by the handle G, and gears H. The weight of the door is counterbalanced by weights J, the chains for which pass over the pulleys K, K. The bolt holes *c*, *c* are for bolting the main framing into the masonry of the culvert. In Fig. 33 provision is made by adjustable wedge blocks *d*, for taking up the wear on the faces of the door and the guiding faces. The wedge blocks are moved forward by the screws *e*, *e*, and the slot holes *f*, *f* in the strips *b* give a range for tightening the bolts.

Penstock also denotes a trough which conducts the water to a water-wheel or turbine.

Pentagon.—A polygon with five sides. For the mensuration and construction of the pentagon, *see* **Polygon.** The following is a

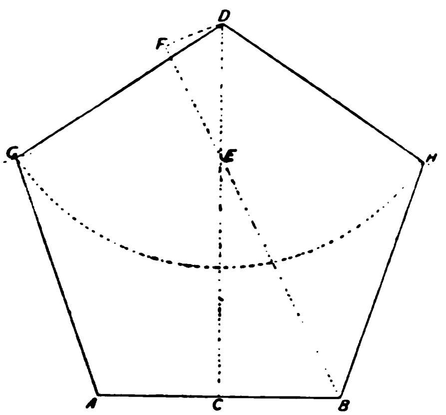


Fig. 34.—Pentagon.

particular method of constructing a pentagon on a given base AB, Fig. 34. Bisect AB and draw a perpendicular CD. Make CE = AB. Join BE and produce the line, making EF = AC. With radius BF and centre B describe the arc FD, cutting CD in D. D is then the apex of the pentagon. With D as centre, and radius AB describe arc GH. With the same radius, and A and B as centres, describe arcs cutting GH in G and H. Join AG, BH, GD, HD.

Percentages.—A percentage is a proportionate amount in each hundred (Lat. *centum*, a hundred). By stating the relation of one number to another, as so many in a hundred, a useful standard of comparison is obtained. The symbol % is used to denote the words "per cent." Thus 10 % means 10 in every hundred, or $\frac{10}{100}$, *i.e.*, $\frac{1}{10}$ of any quantity; $\frac{5}{8}$ % $= \frac{\frac{5}{8}}{100} = \frac{5}{800}$ or $\frac{1}{160}$; $·06$ % $= \frac{·06}{100} = \frac{\frac{6}{100}}{100} = \frac{6}{10000}$. Many percentage calculations may thus be worked by vulgar fractions. Suppose, for example, a brand of high-speed tool steel contains 3 % of chromium. In a hundredweight of this steel there would thus be $\frac{3}{100} \times \frac{112}{1}$ lb. of chromium, or 3·36 lb. If bell metal contains 76 % copper, then the quantity of copper in a ton of bell metal will be $\frac{76}{100} \times \frac{20}{1}$ cwt., or 15·2 cwt.

Conversely, two quantities may be given, and it is required to find what percentage one is of the other. From 1,500 tons of iron ore, 600 tons of metal are obtained after smelting. What percentage is this? The fraction of ore obtained is $\frac{600}{1500} = \frac{6}{15} = \frac{2}{5}$. Take that fraction of 100; $\frac{2}{5} \times \frac{100}{1} = 40$ °/o of iron. Again, in a boiler test, the analysis of a half hundredweight of cinders showed the presence of 23 lb. of unconsumed carbon. What percentage is this? The fraction of unconsumed carbon is $\frac{23}{56}$. This fraction of 100 is $\frac{23}{56} \times \frac{100}{1}$ which, after cancelling, &c., gives approximately 41 °/o.

Certain percentages frequently occur, and it is advisable to commit their equivalent vulgar fractions to memory:—

$2\frac{1}{2}$ per cent.	$= \frac{1}{40}$.	$33\frac{1}{3}$ per cent.	$= \frac{1}{3}$.
5 "	$= \frac{1}{20}$.	50 "	$= \frac{1}{2}$.
10 "	$= \frac{1}{10}$.	$66\frac{2}{3}$ "	$= \frac{2}{3}$.
20 "	$= \frac{1}{5}$.	75 "	$= \frac{3}{4}$.
25 "	$= \frac{1}{4}$.		

Percussion, Centre of.—*See* **Centre of Percussion.**

Perforated Pulleys.—Pulleys having their rims pierced with holes to permit the escape of air from between the belt and rim. The same effect is secured by the pneumatic pulleys of the American Wood Working Machinery Co. A number of spiral crossing grooves are cut round the rim. They occur on the smaller driving, and feed pulleys.

Perforated Saw.—Some circular, and large cross-cut saws have holes at the roots of the teeth. The object is to lessen the work of gulleting, the holes locating and forming the future gullets.

Periodic Law.—*See* **Chemistry.**

Permanent Set.—The degree of deflection of a bar, or member, or structure which remains after the load has been removed. Its amount is strictly determined in specifications.

Permanent Way.—The rails, sleepers, and ballast of the tram lines of railways. It had its origin in the collieries of the North of England for conveying coal from the pit's mouth. Rails of wood were first used. As these wore rapidly, the next advance consisted in nailing plates of wrought iron upon their upper surfaces, by which their durability was increased, and the amount of friction diminished. But this device was in limited use only, and does not appear to have exercised much influence on the growth of the permanent way. The first innovation of much real importance was the introduction of rails of cast iron, which appear to have been made at Coalbrook Dale in Shropshire. The books of the Company have a record of 6 tons of such rails being cast in November 1767, at the suggestion of Mr Reynolds, one of the partners. Rails in this material continued in use for about half a century. Early in the nineteenth century, rails of wrought-iron bar of rectangular section were introduced, and were employed to a limited extent. Various forms of both cast and wrought iron rails were devised from time to time. The first malleable iron rails used on the Stockton and Darlington Railway weighed only 28 lb. per yard. But the first really successful rail was the fish-bellied form of Mr Birkinshaw, of the Bedlington Iron Works, patented in 1820. This type is the parent of the much modified forms in use at the present day. They were 15 ft. in length, with bearings 3 ft. between. The chairs weighed 28 lb. per yard, and were $2\frac{1}{4}$ in. wide on the edge, or "head." Their chief peculiarity was the curving of the under side, so that while the depth of the rail was only $2\frac{1}{2}$ in. at the chairs, it was $3\frac{1}{2}$ in. midway between. This was the type of rail adopted by Mr Stephenson for all his early lines.

One of the most important points wherein the early rails differed from any now in use is, that formerly the rails were flanged, and the wheels flat; now the rails are flat, and the wheels flanged. The early rails, whether wrought or cast, consisted of a flat portion upon which the wheels ran, and a vertical rib against which the edge rubbed, and by which the wheels were prevented from quitting the line. The evil of this arrangement was seen in the excessive friction developed; and if, in order to diminish the friction, the depth of the vertical rib was reduced, the rail was weakened as the square of the depth reduced. The device of making the wheels with flanges was therefore a most important step in advance. Some of the early "plate rails," as they were called, were laid on stone supports, or sleepers, as being more durable than timber, the blocks of stone being bored and plugged with wood to receive the nails used in holding down the rails. Some roads laid on this principle in 1800, by a Mr Benjamin Outram, an engineer of that period, were called "Outram roads," subsequently shortened to "tram road," and "tramway." The "edge rail" and flanged wheel were introduced in 1789 by a Mr Jessop, and used on the Loughborough railway. Birkinshaw's rails were rolled, though of the fish-bellied form, that is, elliptical along their lower edges, and the ends were united with half-lap joints. Their introduction marked a most vital advance in previous practice. The elliptical or fish-bellied rail held its own for a long time, but the parallel rails, first having a single head, and then double headed, eventually superseded them. They were easier to roll, and there was not found the practical advantage in the use of the former that was at first expected. Almost simultaneously with the introduction of rolled malleable iron rails, the method of fastening by means of wedges into their chairs began to be practised, and this also was a most important advance on the methods previously employed, in which pins were employed, both to unite the ends of the rails to each other, and to their chairs, or their sleepers. *See* **Chairs.**

Modern Rails.—At present the flanged or Vignoles rail is used in the United States, the

bull-headed in Great Britain. Formerly the bull-headed rails were turned over after the upper side had become worn, but that is not the present practice. The upper or bull-head is now made heavier than the lower member, and the lower one is made to remain with the top member, when worn, sufficiently strong as a girder to sustain the rolling load. The reason why the early practice of turning over the bull-head rail is not now followed is that it was found that the bottom became indented on the chairs, and then when reversed these made a rough running road.

The first Bessemer steel rail ever rolled was made from an ingot cast at Baxted House, St Pancras, from best Blaenavon pig, and rolled at Dowlais in the autumn of 1856. The first steel rail was laid at the Camden Town goods' station of the London and North-Western Railway in May 1862. A Bessemer steel rail laid at Crewe station in 1863 was turned in 1866, and removed in 1875. It is estimated that the tonnage run over it amounted to 72,000,000 tons, with a loss to the rail of 20 lb. a yard.

The substitution of steel for iron rails was a most important change. The carrying on of the present traffic with iron rails would have been impossible. Even at the time of the invention of the Bessemer process, the life of iron rails only averaged two years, and under heavy traffic much less. Since then, the tonnage carried per mile has more than doubled. The principal main lines had become relaid with steel rails about 1874. The use of steel had the effect of largely reducing the expense of the maintenance and renewal of the permanent way. The average life of a bull-head steel rail is about 24 million tons for each $\frac{1}{16}$ in. wear of the rail head. If a depth of $\frac{5}{16}$ in. is allowed as the limit for wear, this would give 120 million tons as the average life of a steel rail, against $17\frac{1}{2}$ million tons for that of an iron rail, or seven times as much. The wear of rails is not fixed at a definite amount for renewal. From 15 to 20 years is the average life of a steel rail under average traffic. It then loses from 15 to 20 per cent. of its weight, and is used again on sidings. A rail is replaced when it is worn about $\frac{1}{2}$ in. down. Or, a 90 lb., or 82 lb. rail will be allowed to wear to 70 lb. before renewal.

There is no standard either in dimensions, or details of fitting, or in tests adopted by the various companies. Only on broad lines do these approximate; calculations of strains are subordinated to observation and experience, so that the permanent way, some leading types of which are given in Fig. 35, is wholly a product of evolution.

Weights of Rails.—These range between about 80 lb. and 100 lb. per lineal yard; 82 to 90 lb. being the most frequent range. The usual length is 30 ft. Steel is invariably used, but it includes both Bessemer, and Siemens-Martin. Few companies accept basic metal. In testing, much more reliance is placed on impact tests than on tensile tests, or on chemical composition. The tests are made with the rails laid on supports from 3 ft. to 3 ft. 6 in. apart. The falling weight is generally about a ton, falling through 20 ft. on the rail, more or less. After two blows, the permanent deflection must not exceed, say, from $3\frac{1}{2}$ in. to 4 in., nor be less than from 2 in. to $2\frac{1}{2}$ in. Some companies first suspend a dead load from the centre of the rail, the load being from 18 to 20 tons. During this time the temporary deflection must not exceed $\frac{3}{8}$ in., and the permanent set may range from *nil* to $\frac{1}{8}$ in. only.

Supports and Fastenings.—The flat-bottomed rails are fastened direct to the sleepers with bolts and spikes. The bull-head rails are carried in chairs, and are secured therein with keys or wedges, and the chairs to the sleepers with spikes and trenails. Chairs weigh about 46 lb. to 50 lb., without much variation. An important detail is the *bearing area* of the chair on the sleeper. The bearing surface is usually somewhere between 96 and 112 sq. in. Two iron spikes and two wooden trenails secure the chairs. These are of oak, or fir, frequently compressed. The rails are secured by keys of oak, usually placed outside. The rails are jointed with *fish plates.* The plates are usually 18 in. long. They either just fill the space between the top flange of the rail, or they are curved to embrace the bottom flange, and come below it—*suspended* joints, as in B, C, D.

Sleepers.—These are mostly of Baltic red

wood, but Memel, Riga, Scotch fir, and red pine are used. Creosoting is invariably practised. Sleepers measure 9 ft. in length by 10 in. wide, but two companies lay felt between, in the tunnels to deaden noise. The ballast used varies with locality. The lower strata consist of large

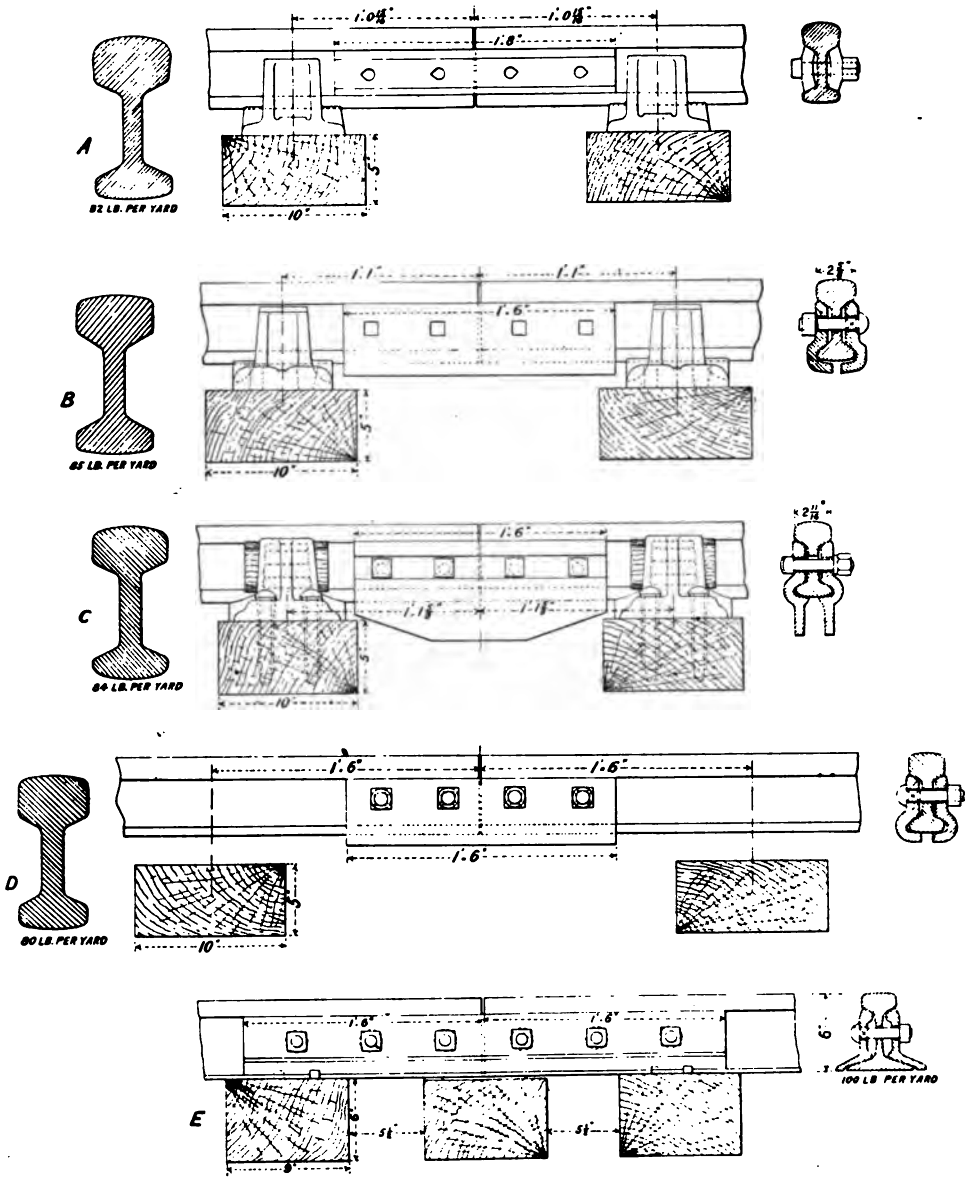


Fig. 35.—Permanent Way.

A. Great Western Railway. *B*. Great Eastern Railway. *C*. London, Brighton, and South Coast Railway. *D*. Cambrian Railway. *E*. New York Central and Hudson River Railway.

by 5 in. deep. Metal sleepers, though tried, are not now laid down on main lines. No packing is used as a rule between the chair and sleeper, stones or slag. The top ballast consists of broken stone, gravel, slag, or cinders. The thickness of each is from 6 in. to 9 in.

Permanent Way Crane. — *See* **Breakdown Crane.**

Perpetual Motion.—A clear appreciation of the properties of matter, and the manifestations of energy is the best antidote to the false theories of perpetual motion which arise at intervals. In many cases inventors have believed in all honesty that they had solved the problem. But too often the claim has been made by rogues and charlatans. A vast amount of misplaced energy and financial loss have resulted from the search for perpetual motion, which might have been saved by a scientific training.

Perspective.—A drawing of an object shows either its actual or its apparent size and shape. The actual size and shape are shown by orthographic projection, and require two views, one from above (the plan) and the other from the front or side (front or side elevation). Engineers' working drawings are examples of orthographic projection. They show the actual shape, and the scale indicates the size of machines, &c. But the apparent shape of an object is frequently very different from the actual shape, and linear perspective deals with the rules underlying the representation of the apparent form and size of objects. These rules are governed by the fact that the rays of light or straight lines from every point in the object to the eye converge to a point within the eye. In plans and elevations such rays continue parallel and perpendicular to the plane of projection.

The main principle in linear perspective is that objects apparently diminish in size as they recede from the spectator. This is a matter of everyday observance in the case of a row of telegraph poles or a block of houses. Tram and railway lines, though we know they are parallel, seem to approach one another closer and closer till in the distance they meet at a point. A fundamental rule therefore is, that lines and edges actually parallel, and which recede from the spectator, must be drawn so as to converge to some point. This point is situated somewhere on the eye level line, that is, a line on a level with the eye at such a height from the ground line that a sheet of paper held horizontally before the eye appears as a line.

Many important laws of perspective may be learned from a study of the photograph of the Hardening Shop, Plate VIII., Vol. V. A photographic lens may be considered as the eye of a spectator. At the further end of the shop against the white wall is a door, and above this a dark spot. The spectator's eye, or the lens, was on a level with, and opposite, this point. Such a point is called the centre of vision, and a horizontal line drawn through the centre of vision gives the horizon line, to which receding parallel lines converge. Lay a ruler along the edges of the bench and along the row of furnaces, and it will be noticed that these edges converge to the centre of vision. Being below the eye level these lines converge upwards. In the same way follow the lines of the central roof girder, the horizontal flue connecting the chimneys, and the upper line of the brick wall on the left. All these converge to the centre of vision, but being above the eye they slope downwards. Note too the diminution in size of the furnace chimneys and the roof columns as they recede. The lines of the horizontal beams below the roof converge neither to the left nor to the right, because though parallel they do not recede from the position of the spectator. Had the spectator been on the extreme left or right side of the shop instead of nearly in the centre, the lines of these beams would have converged. Neither do the cylindrical columns on the other side of the benches converge upwards or downwards, for vertical parallel lines in an object are always drawn vertically with no convergence.

Pet Cocks.—The small cocks on steam boilers attached to the gauge glasses, and through which water or steam are blown off.

Petrol Engine.—A type of internal combustion engine in which the fuel is the vapour of "petrol" ($41{\cdot}86\ C_6H_{14} + 6{\cdot}48\ C_7H_{16} + C_5H_{12}$) diluted with air to form a combustible mixture. In general principles and design the petrol motor strongly resembles a gas engine, but in details several modifications exist. There are two principal types of these motors, the two-stroke cycle, and four-stroke cycle. In the first of these the mixture of air and petrol vapour is first drawn into the crank chamber of the engine, or into a separate pump cylinder. Here

the mixture is slightly compressed (to about 5 lb. per square inch), and when the piston is about at the end of its outward stroke the mixture passes into the cylinder above the piston. Usually the mixture is admitted to the cylinder through ports in the cylinder wall which are uncovered by the piston at, or near, the termination of its out-stroke. On the return of the piston the mixture is compressed, and at the proper moment is ignited, generally by means of an electric spark. During this in-stroke of the piston a new charge of air and vapour is being drawn into the crank chamber, or equivalent device. On the ignition of the charge in the cylinder the gases expand, driving the piston outwards, this constituting the power-stroke. Before reaching the end of the outward or power-stroke the piston uncovers openings or ports in the cylinder walls, thus permitting the products of combustion to escape. The inlet ports for the mixture are uncovered by the remaining travel of the piston immediately after the exhaust ports are fully uncovered. A fresh charge then enters the cylinder, and the cycle of operations continues as before. Hence it will be seen that there is a power-stroke or impulse once in every revolution of the crankshaft, *i.e.*, at each out-stroke of the piston.

The four-stroke cycle differs from the above, and is more economical in fuel consumption. In this type of engine the mixture is drawn directly into the cylinder by the first out-stroke of the piston. The first in-stroke compresses the charge, which is then ignited, causing the impulse or power-stroke. The products of combustion are expelled during the second in-stroke of the piston, and the cycle recommences. Thus there is a power-stroke on each alternate out-stroke, or once for two revolutions of the crankshaft.

Comparing the two systems, the two-stroke cycle has the advantage of making the engine very simple by reason of there being no necessity for valves with their attendant cams and mechanism. Also the turning effort on the crankshaft is more even. But the fuel consumption is high for the power developed. The four-stroke cycle engine is more expensive to construct, requiring an inlet and exhaust valve, cams and rods for operating them, and gearing to reduce the speed of the cam shaft to half that of the crankshaft. The turning moment is necessarily not so constant as in the two-stroke cycle, hence a heavier flywheel is required. However, owing to the higher compression possible and absence of leakage, the four-stroke cycle permits a fuel economy far exceeding that of the other type.

The invention of the four-stroke cycle is due to a celebrated French engineer, Beau de Rochas, who patented the system in 1862. The conditions upon which the success of the engine depended were formulated by the inventor in his patent as :—(1) maximum cylinder capacity with a minimum of circumferential surface; (2) high piston speed; (3) greatest possible compression before ignition; (4) maximum pressure at the commencement of the power-stroke. The second of these is limited in practice, and the third is governed by the fuel used. In the case of petrol engines the compression pressure cannot be made greater than about 95 lb. per sq. in. *absolute*, without pre-ignition of the charge by the heat generated by compressing the mixture. The first condition is fulfilled most nearly in those motors in which the valves open directly into the combustion chamber. Engines which have the inlet and exhaust valves on opposite sides of the cylinder, each in a separate pocket, offer a maximum of circumferential surface, and the design is not to be commended. The heat generated by the combustion of the charge is great: the maximum temperature has not yet been accurately determined, but it is probably in the neighbourhood of 1,800° Fahr. It is therefore necessary to adopt some means whereby the temperature of the cylinder walls can be kept low enough to permit of lubricating the piston. Water jacketing is used for this, except for very small motors, for which air cooling suffices with more or less efficiency. It should be distinctly understood that so far as possible the cooling effect should be confined to the cylinder walls, and not the gases contained therein. The higher the temperature of the gases the greater the efficiency of the motor. The power developed by a petrol engine, or any internal combustion motor on the same

principles, is proportional to the change in temperature of the gases forming the working fluid or fuel. Therefore the greater the range of temperature per cycle, the more the power for a given quantity of fuel.

At the present time a careful investigation of a large number of motors, of many different makes, discloses a number of curious discrepancies. Piston speeds are very variable, and the speed of the gases entering and leaving

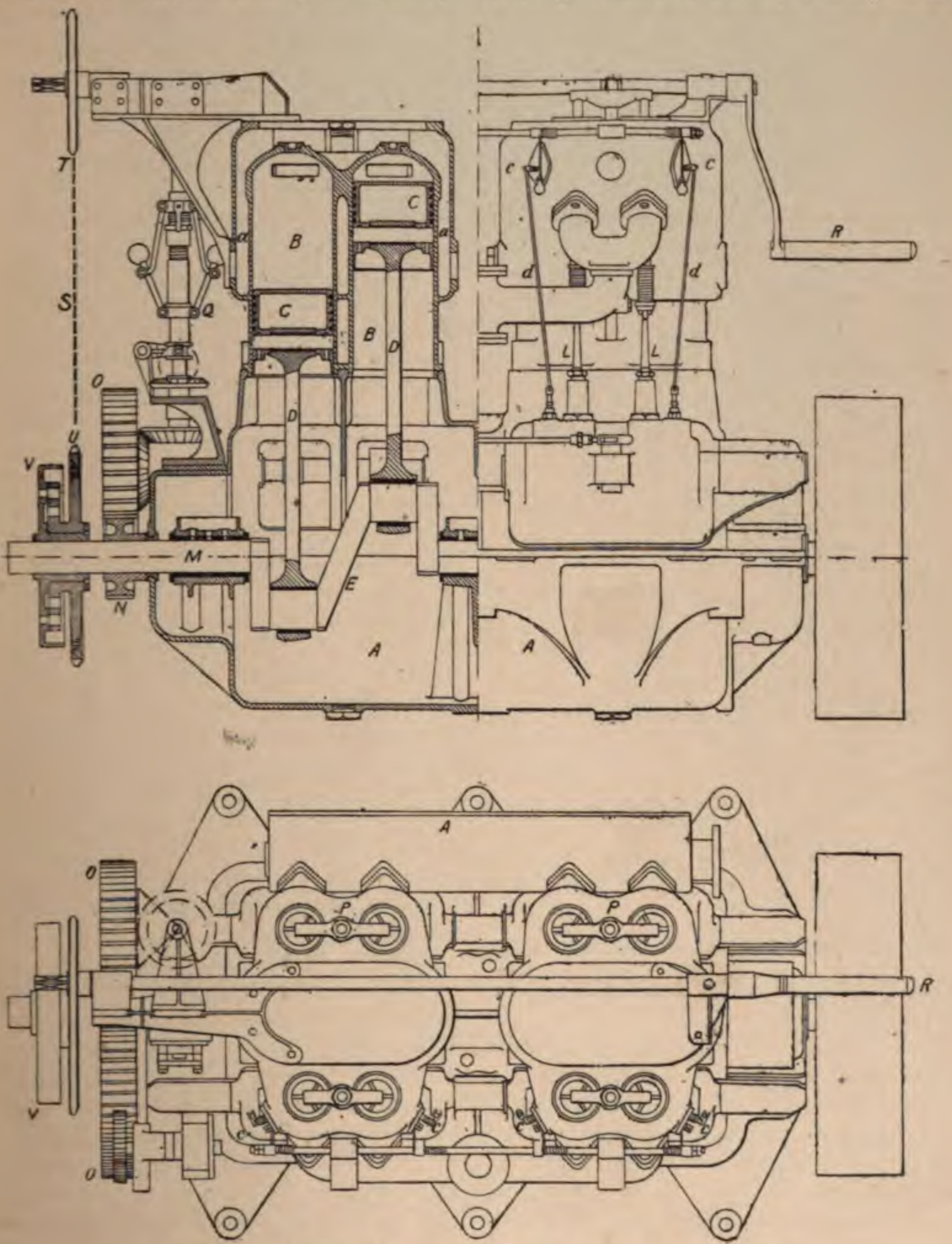


Fig. 36.—Thornycroft Petrol Engine. (Elevation and Plan.)

the cylinder differs between wide limits. Not only is this so for different makes of engines, but motors by the same makers and same design but of different powers are equally faulty. There does not appear to be any uniformity, or any approach thereto, in the ideas of designers on the subject of such fundamental principles as piston speed, speed of fuel passing into cylinder, speed of exhaust gases, and allowable temperature of cylinder walls. That there

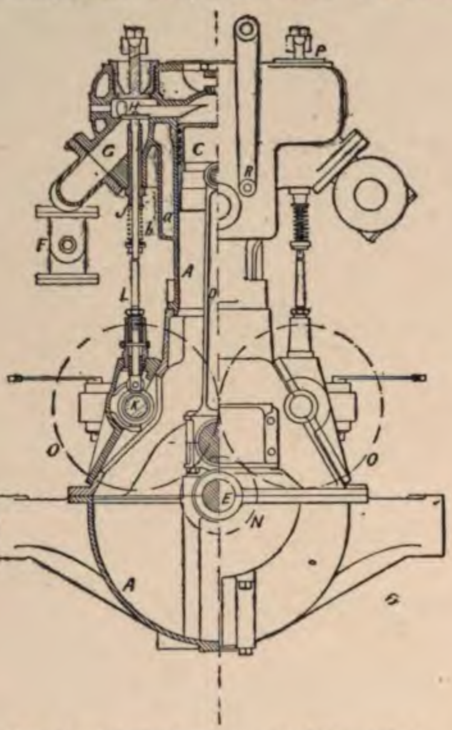


Fig. 37.—Petrol Engine. (End Elevation.)

is a best possible value for each of these points is certain, and their adoption is advisable.

Future development of petrol engines would appear to lie along the lines of a perfected two-stroke cycle combined with cooling of the charge after compression and before ignition, thus increasing the range of temperature and improving the turning moment, resulting in greater fuel economy, and a smaller engine for a given power.

Figs. 36 and 37 illustrate a marine petrol engine by Messrs John I. Thornycroft & Co., Ltd. The engines are mounted on the crank casing A, which is made of aluminium when lessening of weight is a consideration, but generally of cast iron. It is enclosed to hold the lubricant, and is fitted with doors. The cylinders B are fitted with spigots into bored holes on the top of the chamber, and are bolted to its top face. The cylinders are surrounded with water-cooling jackets *a*. The pistons C are of trunk form, solid, and fitted with Ramsbottom rings. The connecting rods D, which are steel stampings, are bushed at both ends. The crankshaft E is of solid steel. The carburetter is not shown in the drawings, but it is seen in the photograph of another engine in Fig. 38, Plate IV. It receives the air inlet, and from it the supply pipes go to the cylinders. The air being drawn into the carburetter by the motor, rushes by a nozzle from which petrol is drawn in a fine spray, and being volatilised, goes through the throttle valve F to the inlet pipe G, to the cylinder. Its volume is controlled by the inlet valve H. The valve rods are seen at J, actuated from the cam shaft K, which operates the tappet shafts L, through rollers in contact with the cam shaft. The latter is actuated from the shaft M, through the half-speed gears N, O, O, the valves being thereby opened and closed once during two revolutions of the crankshaft. The springs *b* opposed to the lift of the cams close the valves sharply when the eccentric part of the cams has passed. The exhaust valves are on the opposite side of the cylinders, and are similarly operated with a cam shaft, &c., as seen in Fig. 37. The governor is seen at Q actuated through bevel gears from one of the half-speed shafts whence the throttle valve is controlled.

Firing.—In this engine a low-tension magneto system is employed. The lower ends of the permanent magnets carry two pole-pieces, within which there is a fixed armature wound with insulated copper wire, with a rotating soft iron sleeve between. The sleeve has two slots cut in it in opposite sides, with the result that the lines of force which cut the coils of the armature vary from maximum to nothing, and *vice versa* twice during a revolution, producing four sparks per revolution. At *c* the sparking plugs are seen screwed into the cylinders; *d*, *d* are the tappet rods actuated by cams on the half-speed shaft: they work the mechanical make and break inside the cylinders. A

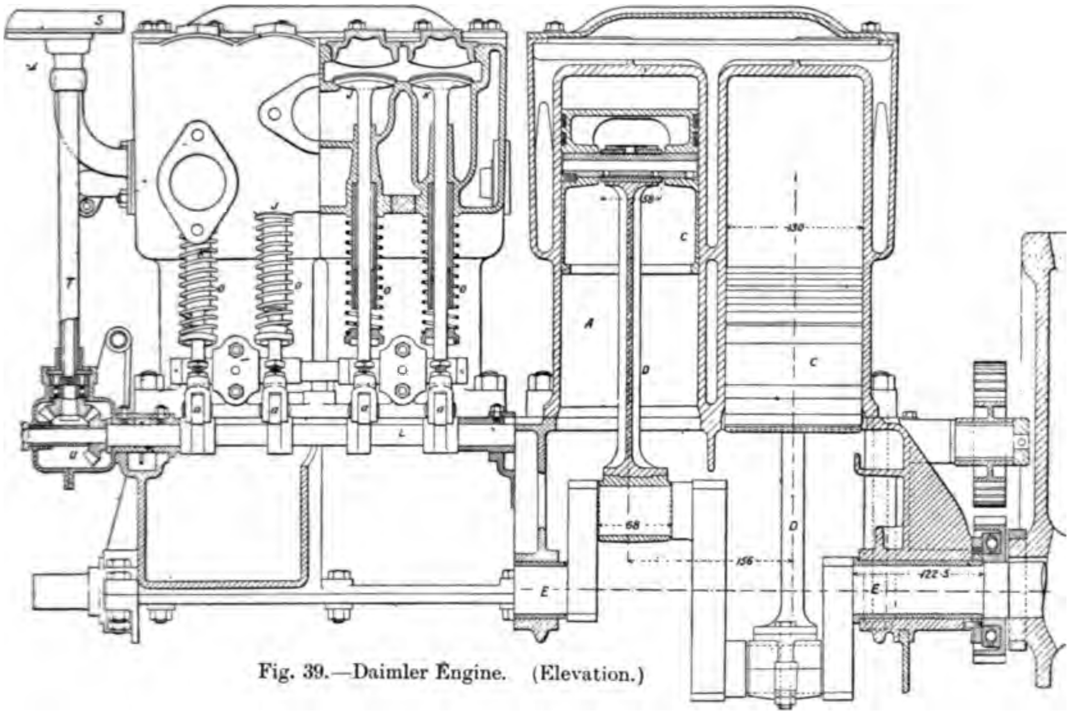


Fig. 39.—Daimler Engine. (Elevation.)

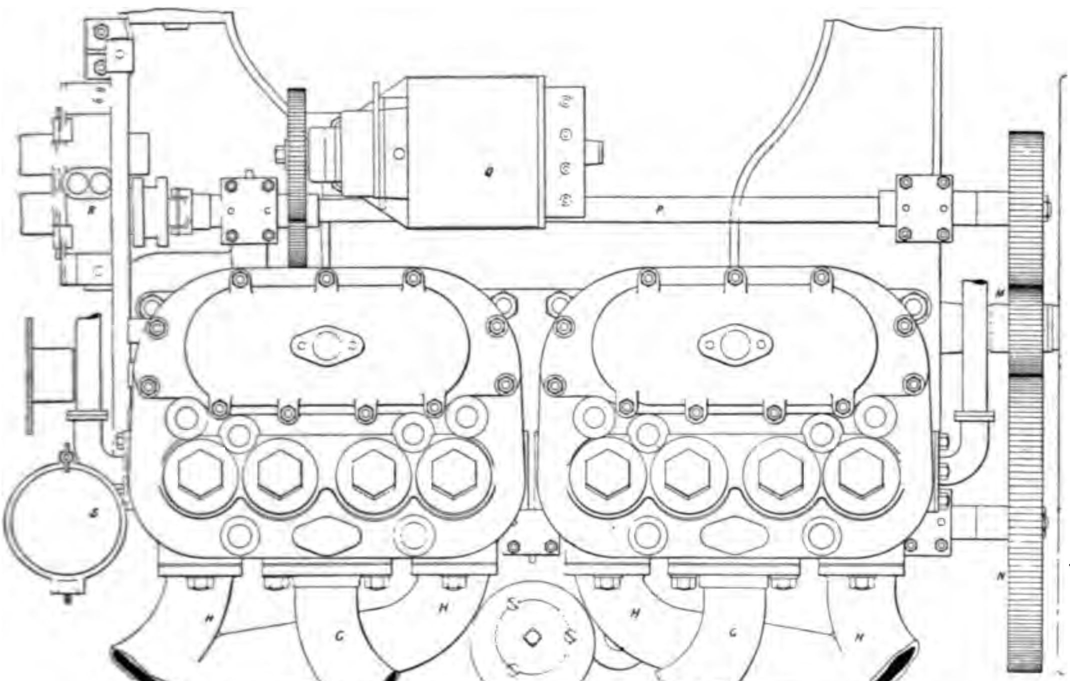


Fig. 40.—Daimler Engine. (Plan.)

contact breaker is located adjacent to each plug. The starting handle is seen at R, the shaft of which is connected with the crankshaft by pitch chain at S, the wheels being shown at T, U. A free wheel clutch is shown in section at V. A pair of ratchets within the casing surround the clutch which is on the crankshaft. The chain wheel U is attached to the ratchet wheel, which acts only in one direction. On starting, the turning of the chain wheel U turns the crankshaft through the ratchet and pawls. When the engine fires, the speed of the crankshaft outruns that of the chain wheel, and the centrifugal effect causes the pawls to fly out of contact with the ratchet wheel, and the engine runs independently.

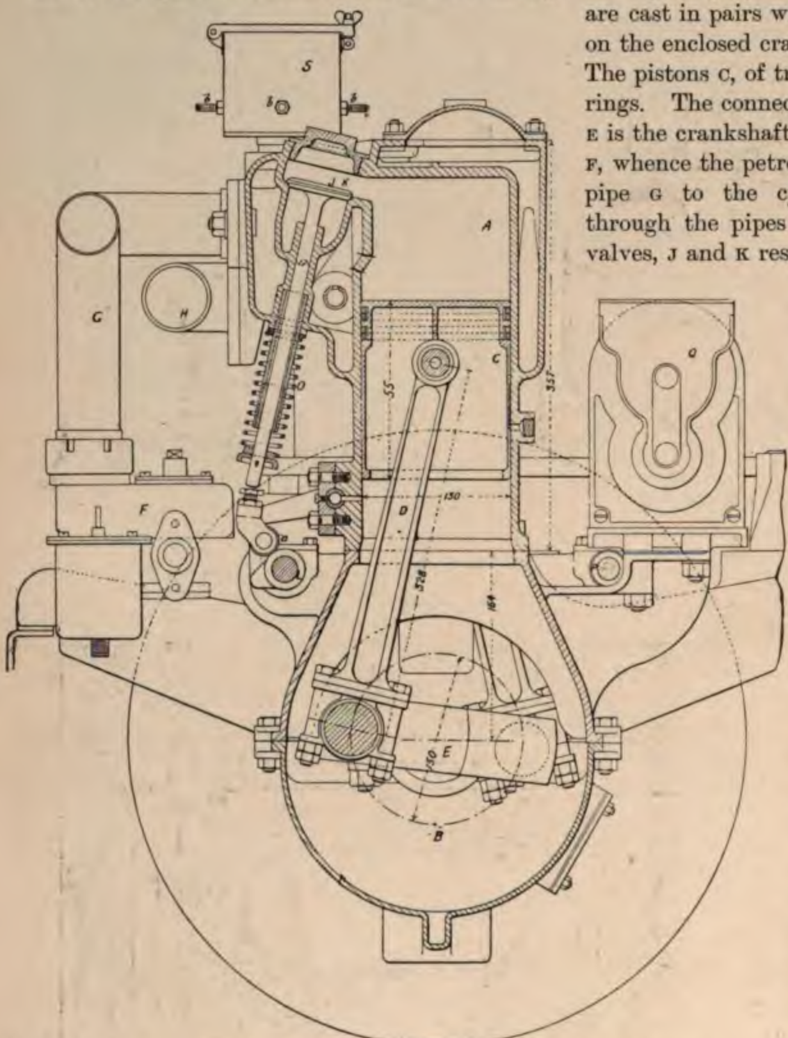


Fig. 41.—Daimler Engine. (Transverse Sectional Elevation.)

Figs. 39 to 41 show one of the motors by the Daimler Motor Co., Ltd., and Fig. 42, Plate V., a photograph of the same. The cylinders A are cast in pairs with water jackets, and bolted on the enclosed crank chamber B, of aluminium. The pistons C, of trunk form, have Ramsbottom rings. The connecting rods D are of H section. E is the crankshaft. The vaporiser is shown at F, whence the petrol vapour passes through the pipe G to the cylinders, thence exhausting through the pipes H. The inlet and exhaust valves, J and K respectively, are on one side of the cylinder, and are alike in shape and dimensions, to be interchangeable. They are operated by the cam shaft L driven by the half-speed wheels M, N, the cams thrusting against the rollers *a*, the pressure of the springs O closing the valves when the cam has passed.

P is the lay shaft driven from wheel M, and driving the magneto Q, and the geared pump R. This magneto supplies current to the sparking plugs, as an alternative to the high-tension circuit, Fig. 43. This view illustrates the plan of wiring; and the distributor case S in the previous figures, but with the cover removed to show the distributor block A in Fig. 43. This block rotates within the bushes B, so making and breaking the primary current. The block A is so designed that the distribution of the secondary or high-tension current to the insulated plugs C, and thence to the sparking plugs D, synchronises with the opening and closing of the primary circuit. The distributor case S, Figs. 39 to 41, can be rotated on its axis, in order to quicken or retard the timing of the spark. The

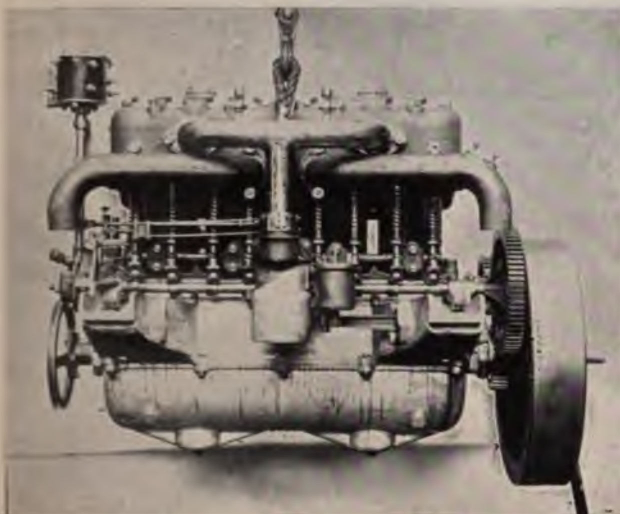


Fig. 42.—PETROL ENGINE. (The Daimler Motor Co., Ltd.)

Fig. 45.—HALDEN ELECTRIC COPIER.

Fig. 46.—ELECTRIC COPIER, SWUNG HORIZONTALLY.

Fig. 47.—CONTINUOUS ELECTRIC COPIER.

(J. Halden & Co.)

To face page 42.

distributor block A is keyed to a vertical shaft T, Fig. 39, which is driven by means of bevel gears U from the end of the cam shaft. *b*, *b*, *b* are the sparking plug terminals.

Paraffin.—This is used successfully in some types of petrol motors; Messrs Thornycroft arrange their petrol engines when desired with a vaporiser, so that the carburetter can be disconnected by a change-over valve, and paraffin be used, subsequent to starting with petrol. Or, the engine may be started entirely on paraffin, by heating the inside of the vaporiser with a blow-lamp.

Petroleum.—This term is applied to a great variety of inflammable liquids with carbon and hydrogen as essential constituents. Mendeleef and Berthelot considered petroleum of inorganic

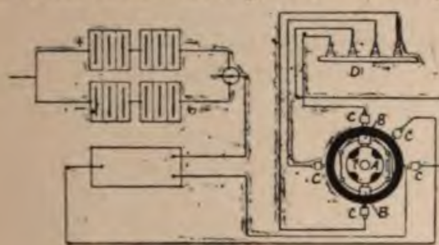


Fig. 43.—Distribution Box.

origin, the opinion of the former scientist being that it was produced by the action of water on carbide of iron in the earth's interior, while Berthelot suggested that it was formed by the action of water impregnated with carbonic acid gas on free alkali metals in the interior of the earth. The weight of authority, however, would rather indicate that it is of organic origin, having been produced by the slow decomposition of animal and vegetable matter under great pressure.

Petroleum occurs in practically all geological strata, commercial supplies being drawn from the coarse sandstones and crystalline limestones whose pores contain the oil imprisoned by overlying beds of impervious clay or other mineral. Nearly half of the world's supply of petroleum comes from the United States. With the exception of some of the Atlantic States and those west of the Great Lakes it occurs in all parts of the Union, but varying of course in quality and quantity. The most productive are the Appalachian oil fields. Many of the Canadian provinces are rich in oil bearing strata, and only await development. Nearly 40 per cent. of the world's production comes from the famous oil wells of Baku in Russia. The amazing outflows from this district have been known and utilised from the earliest times. The remaining supplies are drawn from the Dutch East Indies, Austria, Roumania, South America, Germany, Italy, Japan, Assam, and Burma.

Illuminating and lubricating oils similar in composition to those obtained from crude petroleum are also obtained by the destructive distillation of bituminous shales found in Scotland, France, New South Wales, New Zealand, &c.

The primitive method of obtaining oil by sinking a shallow well, as for water, has only been superseded during the last fifty or sixty years by the use of percussion or rotary drills actuated by steam power. The usual process consists in digging a shaft some 12 or 14 ft. deep, and 8 to 10 ft. square, a pipe armed with a steel shoe then being used to pierce the varying strata as far as the nature of the rock permits. When hard rock is reached the drill is brought into operation. Water is introduced into the well, and mixing with the finely broken rock is withdrawn from the borehole by a sand pump.

The depth to which boring is carried varies from 300 ft. to 3,000 ft., though the latter figure has been considerably exceeded in certain cases. It is, of course, frequently necessary to support the walls by means of an iron casing.

As the petroleum is generally held under pressure, a natural flow of oil commences in most cases when a well is completed. When the pressure becomes subsequently relieved recourse is had to pumping, as in the majority of oil wells in the States. Sometimes the pressure is so great that a fountain or "spouter," as it is called, bursts forth to a height of two or three hundred feet. As it falls it is accumulated in prepared reservoirs. Being dependent on the pressure, the duration of a spouter obviously varies from a few days to a twelvemonth or even more. Enormous quantities of sand are ejected with the oil, frequently giving rise to considerable trouble. From the reservoirs the oil is transported to centres hundreds of miles distant by pipe lines. In the U.S.A. the total length of iron and steel oil tubes probably exceeds 30,000

miles. The trunk lines, which are capable of sustaining a pressure of 2,000 lb. per square inch, are 18 ft. long, with a diameter of 6 or 8 inches. The oil is pumped through the system, travelling at about 3 miles an hour. The crude oil is stored in huge cylindrical tanks at the chief centres, as New York, Philadelphia, Chicago, Baltimore, Buffalo, &c.

Varying with the locality there is a great difference in crude petroleum. It may be almost colourless or nearly black, mobile or viscous, without odour or disagreeably odorous. Specific gravity varies between ·77 and ·10. From the chemical aspect crude petroleum is a combination of carbon (79·5 per cent. to 88·7 per cent.), and hydrogen (9·6 per cent. to 14·8 per cent.), with minute quantities of nitrogen, oxygen, and sometimes sulphur. According to the way in which the atoms of carbon and hydrogen are grouped, the hydrocarbon compounds of petroleum are classified as paraffins and naphthenes. The paraffins are represented by the formula C_nH_{2n+2}, n representing the number of atoms in the formula; the naphthenes or olefines contain two atoms less hydrogen, and are represented by the formula C_nH_{2n}. It will thus be seen that an extensive series of hydrocarbons can be obtained from petroleum, and since the boiling point is lowest for those hydrocarbons with a lower proportion of carbon, and rises with an increased proportion of carbon, the crude oil may be separated into a series of products by distillation. The oil is heated in a horizontal cylinder, and the vapour passes into a condensing pipe or worm, surrounded with cold water.

The first portion to distil over is benzine (not to be confounded with benzene), naphtha, or petroleum spirit. Gasolene and petrol, used in the internal combustion engines of motor cars, distil over at this stage, and are obtained by the redistillation of benzine. As the temperature rises, kerosene, used for illuminating purposes, passes over, and both this and benzine are purified by agitation with sulphuric acid. When the specific gravity of the crude oil lies between ·77 and ·9, the proportion of kerosene will exceed that of other oils; when specific gravity lies above ·9, lubricating oils are in excess. Following kerosene come the lubricating oils, and the heavy residuum is utilised in the preparation of paraffin wax and vaseline. If lighter oils are mixed with kerosene the flash point is lowered. This is the point at which it will give off inflammable vapours, and is thus a matter of considerable importance in lamp oils. By the Petroleum Act of 1871 the minimum legal flash point was 100° Fahr. But the method of testing the oil (in an open cup) was proved to be fallacious, and Sir Frederick Abel suggested an improved method of testing in a closed cup, and this method was subsequently adopted. Oils whose flash point was 100° Fahr. by the "open" test were thus shown to flash at 73° Fahr. by the "close" test.

In addition to illumination and lubrication, the uses to which the products of petroleum are put may justly be termed multitudinous, and can only be barely enumerated here. Gasolene, specific gravity ·642 to ·648, is used in internal combustion motors, and on redistillation separates into cymogene and rhigolene, which are used in freezing machines, and in surgery as anæsthetics. Petroleum spirit, with a slightly higher specific gravity, ·68 or higher, is used for the propulsion of motor vehicles, launches, and submarines; benzolene, specific gravity ·70, is used for dry cleaning. Petroleum also enters into the manufacture of carburetted water gas, serves as fuel for steam raising in stationary and locomotive engines, and is employed in internal combustion engines in such types as the Diesel, Hornsby-Akroyd, Tangye, and Priestman engines. Petroleum is also used for the preservation of roads, for soap manufacture, as an insecticide, in the preparation of varnish and paint, and forms 5 per cent. of the composition of cordite.

Phœnix Column.—A column of circular section built up of four, six, or eight rolled segments, riveted through flanges.

Phosphor Bronze.—Bronze with a slight admixture of phosphorus. It can be cast, rolled, and drawn into wire. It is valuable for bearings and pump rods. Proportions are:—Copper, 89·5 per cent.; tin, 10 per cent.; phosphorus from 0·1 to 0·5 per cent. The ultimate strength ranges from 15 to 22 tons.

Phosphorus.—P. 31; melting point, 44°; boiling point, 290°; specific gravity, 1·8. Hav-

ing a great affinity for oxygen, phosphorus is not found free in Nature, but in combination with oxygen, and with calcium in bones, the brain, nervous tissues, and urine. It occurs in two allotropic forms. At ordinary temperatures it is a waxy, soft, semi-transparent, pale yellow solid, with a characteristic odour. At low temperatures it becomes brittle. It possesses the peculiar property of giving off white luminous fumes in the dark if exposed to the air. The warmth of the hand, friction, or a slight blow causes it to ignite, forming P_4O_{10}. It is therefore stored in water.

Heated to about 240° Cent. ordinary phosphorus undergoes a remarkable change. It becomes deep red in colour, with a higher specific gravity, 2·1; is not ignited by friction, or affected by the air; is insoluble in the solvents for ordinary phosphorus; and does not ignite till heated to above 260° Cent.

Ordinary phosphorus is a powerful poison, and those exposed to its vapour, as in the manufacture of matches, are liable to necrosis of the jaw, especially when suffering from decayed teeth. Red phosphorus, however, is not poisonous, and is used in the composition at the side of match boxes, on which safety matches are struck. Safety match heads contain no phosphorus.

Phosphorus is prepared commercially by heating the white ash from calcined bones with two-thirds of its weight of strong sulphuric acid:—

$$Ca_3 2PO_4 + 3H_2SO_4 = 2H_3PO_4 + 3CaSO_4.$$

Calcium sulphate, $CaSO_4$, is separated by filtration through linen; and the liquid, phosphoric acid, is mixed with charcoal and heated to redness in earthenware retorts, whose necks dip into water. During this process metaphosphoric acid, HPO_3, is formed, and on further heating phosphorus distils over, collecting under the water in yellow drops. The stages are shown in the equations:—

$$2H_3PO_4 - 2H_2O = 2HPO_3.$$

$$4HPO_3 + 12C = 2H_2 + 12CO + P_4.$$

Phosphorus is of chief interest to the engineer as being one of the constituents of bronze and other alloys. It acts as a deoxidiser, assisting in the removal of gases, and making the alloy harder, more compact, and tenacious. Phosphorus renders steel brittle. It should not exceed ·02 per cent. in steel for gun-barrels and dies, to ·08 in axles and rails, and ·01 in high carbon steel. Steel for structural work should not contain a greater percentage than ·06 of phosphorus.

Phosphoric acid occurs in iron ores in varying quantities, being greatest (1·8 per cent.) in Cleveland ironstone, and Northampton limonite (1·3 per cent.), and least (·03 per cent.) in Swedish magnetite. *See* **Bessemer Pig, Phosphor Bronze, Steel.**

Photography—Workshop.—Workshop photography has now become a specialised branch of the art, and firms which a few years ago occasionally called in the aid of a local photographer now possess their own apparatus, studio, and operators. This is not to be wondered at, for the difficulties and problems which beset the technical photographer differ from those which the ordinary professional photographer meets with. Moreover the elaborate catalogue with half-tone blocks has come to stay, and the equipment of a factory studio is cheaper in the long run.

The questions of **Camera**, and **Lens** have been dealt with under their respective titles. With regard to plates, a fast quality is used for the majority of photographs. The best plan is to adopt a special rapid brand and stick to it. Plates should invariably be "backed" to prevent what is known as halation, a spreading of the high lights beyond their boundaries, as seen round the windows in some photographs of shop interiors. In machinery, halation is caused by the brightly reflected lights from polished parts. Another difficulty arises from the different colours sometimes present, the yellow of brass, reddish colour of copper, and bluish tint of bright steel. In photographs the colours at the red end of the spectrum appear very dark, as they have but little actinic value. (Red or orange lights are therefore used in the dark room.) A red rose will appear almost black. Violet and blue at the other end appear nearly white. To obviate this, orthochromatic plates are used, with the addition of a transparent yellow screen in front or behind, or between the lenses. A lemon-yellow screen satisfies most requirements, but for copper work

where reds predominate an orange screen is necessary. These screens lengthen the exposure, which again is another factor to be dealt with in considering what depth of yellow to use.

As regards the subject to be photographed, much may be done before the photograph is taken, to ensure a good picture. The light, position, and surroundings are frequently beyond the control of the operator. Parts in deep shadow may be relieved by reflection from judiciously placed sheets of bright tin, newspapers, or white sheets, though, of course, these must not appear in the negative, except when the object is to be "blocked out." Bright points may be dulled with a little putty, while many firms go to the trouble of painting bright steel work, as in engines, with a flat dark grey colour—an operation well worth the time involved. Not only does this deaden bright parts and smooth over roughnesses, but parts in deep shadow are thereby made lighter. If the subject is not to be blocked out, a background is generally advisable. Benches, belts, machinery of varied kinds, doors and windows, &c., in the background all help to confuse the outlines and details of machinery. If the subject is small a proper background with uniform tint can be used. Frequently this is impossible, and recourse must then be had to blocking out as described below.

Development calls for little remark. A photographer who keeps always to the same developer can do almost what he wishes with it, and knowing the special difficulties of the subject on the undeveloped plate will mix his solutions in the correct proportions. Good contrast is needed to make a good block, and a flat print is useless. But excessive contrast is also undesirable, and for this reason single solution hydrokinone developers should, as a rule, be avoided.

To eliminate the confusing effect of surrounding machinery or an unsightly background, the process known as blocking out must be resorted to. This consists in carefully working round the machine, and painting out the entire background and surroundings so that the subject is entirely isolated. This is done on the film side of the negative, with some opaque preparation, of which there are several kinds sold for this purpose. Indian ink is scarcely suitable, as it cracks on drying. The negative should be placed on a retouching desk, and with a bevelled rule or straightedge, and drawing pen, straight lines should be ruled against all the horizontal edges bordering on the background. Vertical edges are next dealt with, and then the drawing pen is discarded for a medium sable pencil for working round curves. This is a delicate operation, and requires a steady hand. The arms and rims of small wheels, and the teeth of gear wheels are especially difficult. The outlines of the machine being now completed, the surrounding areas can be covered with a large brush. If the negative is large and the areas of considerable size, orange paper may be pasted on the glass side. Many examples of blocked-out subjects occur throughout these volumes. In Volume V. such photographs are seen in Plate IV., Figs. 55 and 57.

Of the multitude of printing processes, engineers use but two, the print-out process on gelatino-chloride paper (P.O.P.), and the development process on bromide paper. Where prints are required for blockmaking they must have plenty of contrast—for the half-tone process has a degrading effect on the most brilliant of prints—plenty of detail, rather lightly printed than the reverse, and should be larger than the required block, to allow of reduction. Silver prints (white P.O.P.) should be toned to a cold colour. Red tones are bad.

Photo Prints.—A photo print is a copy of a tracing produced by the action of light upon a chemically prepared surface. There are several processes in use; the most widely adopted is that known as the Ferro-Prussiate, whereby ordinary blue prints are produced, having a ground of Prussian blue with white lines thereon. A similar process, but producing blue lines on a white ground, is used to some extent, but is rapidly giving place to the black line or Ferro-Gallic process.

The blue prints are cheaper and more readily made than the black line, but they have the disadvantage of not being colourable; the black line on the contrary can be coloured quite as well as a hand-made drawing.

The basis of these processes is the action of light on the salts of iron which are present on

the paper. The principal chemical change is the conversion of a ferric salt to a ferrous salt on that portion of the paper which is exposed to the light. After this has taken place the print is *fixed* by simply treating it with a water bath. In the case of the blue-line process, development takes place in a bath containing a saturated solution of yellow prussiate of potash, and fixing in a weak solution of hydrochloric acid, water baths also being used.

Exposure to light is done in a frame with a glass front. The tracing to be copied is laid on the glass, and the sensitised paper is placed behind the tracing so that the light passes through the tracing to the paper. The earlier frames were rectangular and of a sufficient size to take the largest sheet of paper in use; the tracings and paper were held up to the glass by means of felt and boards and springs; exposure was made to sunlight. These frames are still

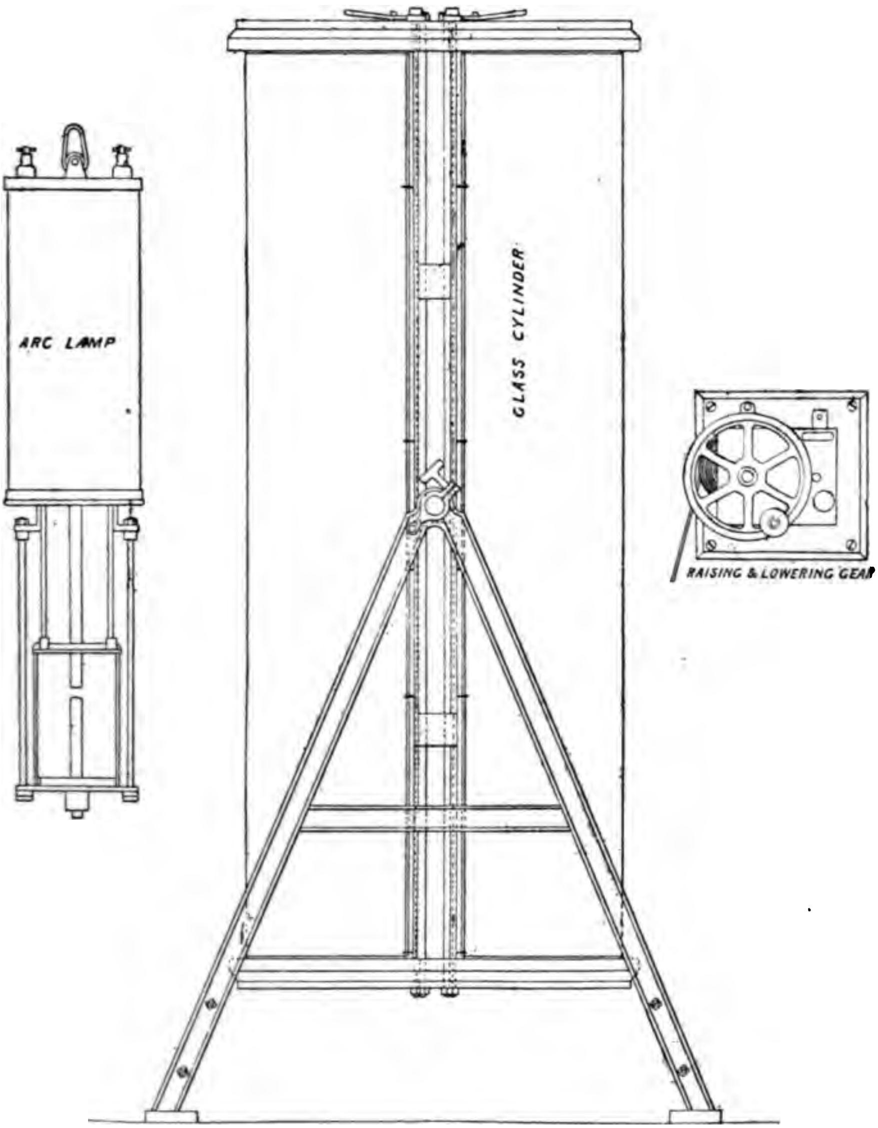


Fig. 44.—Halden's Arc Lamp Duplex Radial Photo Copier.

in use, and for occasional prints are quite convenient, but they are totally inadequate to meet the requirements of large works and offices. Printing in dull weather is very slow, and the day's output during the winter months is very small indeed. Electricity is now used, and as a consequence printing may be carried on by day or night without regard to sunlight or weather.

The frame of the electric copier generally takes the form of that shown in Fig. 44, and in the photo, Fig. 45, Plate V., and consists of a glass cylinder mounted on a suitable frame, and fitted with exterior canvas sheets, and means for tightening the same around the cylinder; in the one illustrated the cylinder is pivoted on the frame so as to swing into a horizontal position, Fig. 46, Plate V., for convenience in placing and removing prints (Halden's Patent). The tracing is laid next to the glass and the sensitised paper next to it, the canvas sheets being then strained over and fastened. Light is provided by a suspended arc lamp, which can descend through the cylinder at any speed desired to suit the exposure of various papers.

The size of this type of electric copier is limited, because of the difficulty of obtaining large sheets of glass of sufficient strength and transparency. They are made to take the largest sheet of paper ordinarily in use, but for the great plans used in shipyards, &c., a different type of copier is made.

Continuous Copier.—By means of the continuous copier, Fig. 47, Plate V., a print of any length can be produced. Three arc lamps are fixed in the centre of the machine, and the tracing and paper are conveyed past them by means of electrically driven rollers; the sensitised paper is fed from a roll located on the copier. Various apparatus are used in connection with the finishing and drying of prints, such as continuous water baths, gas and electric drying machines, &c., but which do not call for any special description.

There is one serious defect in a photo print, and one which cannot be avoided; the water bath and the drying of the print alter the dimensions of the paper, and the print is therefore not true to scale. Another defect is that it cannot be absolutely guaranteed permanent; unless the print has been most carefully made it is liable to fade when exposed to light for a considerable time. Various attempts have been made to obviate these disadvantages, and there are at present in use several secret processes which claim to produce permanent copies true to scale.

So far as is known publicly the principle adopted is as follows:—When the ordinary blue print is taken from the printing frame it is laid face downward on a sheet of prepared gelatine spread over a zinc plate. This gelatine contains a certain chemical which has an affinity for the ferric salt left on the print. As this residue only occurs where the lines are on the tracing, a negative is thus obtained on the gelatine. Over this negative is rolled ordinary printer's ink of any colour, and copies can then be transferred to any paper by the simple process of taking impressions by hand. There is no water used, and the copies are as permanent as any ordinary printed matter. The blue print may be washed and used as usual if desired, but in this process it is only required as a means to obtain the gelatine negative.

Pi.—The letter pi, π, is the sixteenth of the Greek alphabet. Being the initial letter of the word perimeter, it is used to denote the ratio of the circumference of a circle to the radius, and this is obviously the same for all circles. Ancient mathematicians attacked this problem, but the ratio cannot be represented exactly by any two whole numbers. For practical purposes π may be taken to equal $3\frac{1}{7}$. Then if the diameter of any circle be 1 ft., the circumference is $3\frac{1}{7}$ ft.; if the diameter be 42 in., the circumference is $42 \times 3\frac{1}{7}$ in., and so on. Thus the rule for finding the circumference of a circle is, diameter $\times\ \pi =$ circumference. For greater exactness π may be taken as $\frac{355}{113}$, or 3·1416. To fourteen places of decimals the ratio becomes 3·14159265358979, but it has been calculated to hundreds of decimal places.

Picker.—A small vent wire, when used for withdrawing small patterns from their moulds.

Pickering Governor.—In this the balls are connected to the centre of cambered springs of flat steel, which are sufficiently elastic to accommodate themselves to the centrifugal

action of the balls. The effect of increase in speed is to draw the ends of the springs inwards, so lessening the opening of the throttle. The springs either act on a sliding collar which actuates the throttle valve lever, or they operate directly on the valve through the valve spindle, placed centrally below.

Pickle, Pickling.—Relates to the removal of oxide, scale, or dirt from articles, iron and steel chiefly, but also from copper alloys, preparatory to coating the surfaces with some preservative, or to soften them previous to machining, and so save the edges of the tools. The extent of the application of this process is very wide. It includes the small castings and forgings in many engineers' shops, sheets of iron and steel which have to be galvanised or painted, rods which have to be drawn into wire, plates and sheets which have to be rolled or stamped, and tin plates. Often the pickling process has to be repeated twice or oftener, as when articles are annealed the scale has to be removed after each annealing.

The acids used are sulphuric, hydrochloric, and nitric, the first two for iron and steel, the third for brass. But the proportions vary much. Generally pickling solutions are heated to increase the activity of the acids. The particular oxide also governs the nature of the acids used. Ferrous oxide, FeO, is easily soluble in hydrochloric and nitric acids, but scarcely at all in sulphuric. Ferric oxide, Fe_2O_3 (common brown rust), is soluble in dilute hydrochloric acid and dilute sulphuric. The black or magnetic oxide, Fe_3O_4, or FeO, Fe_2O_3 is soluble in hydrochloric acid. As the oxides are more difficult to dissolve than the metal, the metal in contact with black oxide or scale is more readily attacked than a clean surface, because the scale is electro-negative to the iron. The following selections illustrate a few variations in the practice of pickling. 1 part of sulphuric acid, or hydrochloric acid to 10 of water is used for removing mill scale from forgings and plates. 1 part hydrochloric acid to 19 of water, for removing black oxide from steam pipes, boiler, and collector tubes. Or, 1 part to 39 parts of water. For removing mill scale from structural steel previous to painting:—1 part of hydrochloric acid to 1 of water, cold. Or, hot dilute sulphuric acid of a strength of from 20 to 28 per cent. solution. A 10 per cent. solution requires several hours of immersion. Pure hydrochloric acid may be used for removing rust rapidly from iron and steel. The work should afterwards be rinsed rapidly in cold and hot water, and dried in sawdust. For iron castings, 1 of sulphuric acid to 4 of water for rapid working, or 1 to 10 of water for slower action. It may be used cold, or kept at a temperature of about 150° Fahr.

Picric Acid.—Or trinitrophenol, $C_6H_2(NO_2)_3OH$, is obtained by the action of nitric acid on phenol or carbolic acid, C_6H_5OH, one to three atoms of hydrogen in the latter compound being substituted by NO_2. Picric acid forms bright yellow crystals slightly soluble in water. It is used as a yellow dye, and as an explosive in **Lyddite**, and **Melinite**.

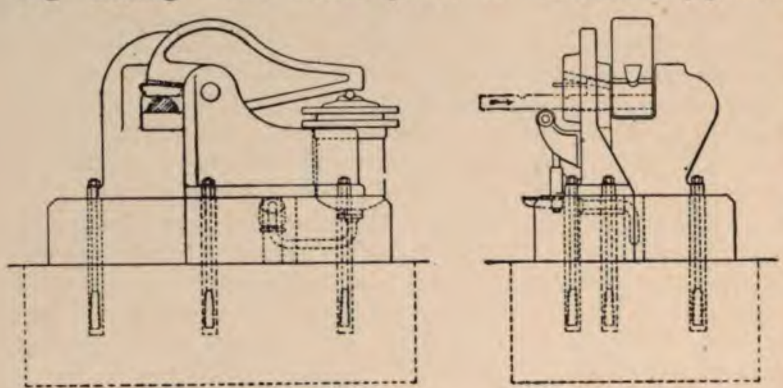
Piece Work.—Work, the labour cost of which is fixed beforehand, mutually by the firm and the hands. Though it appears an ideal arrangement it has seldom proved satisfactory in practice. Conventional views with regard to the amount that men should be permitted to earn, based on the standard weekly wages, have, more than any other cause, interfered with the permanence of piecework prices. Men have, in their own interests, restricted their output to the equivalent of time and a quarter, time and a third, or time and a half, according to the unwritten usage of their shops, in order to prevent the cutting of prices should these rates be exceeded. Another difficulty lies in the readjustment of prices to changed conditions, such as improved machinery and appliances, by which labour is lessened. There are some classes of work again for which it is difficult to fix prices beforehand; as work which is not of a repetitive character, jobbing work, that which requires special tackle, much pattern, and foundry work, and forging.

The best conditions under which piecework prices can be settled are those in which machinery is chiefly employed. It is therefore largely adopted in plate, and machine moulding, and in the machine shop. In the boiler and plating shops riveting is paid by the hundred, work priced by the ton, varying with character; and forgings per hundred in the stamping

department of the smithy. When improved machinery and methods are introduced, then readjustment of prices can be effected by the first job or two done as tests by which to settle the new prices. But when a price is once fixed it should not be cut so long as the conditions remain unchanged, for that brings the system into disrepute. *See* **Premium Systems.**

Pig Bed.—The bed of sand in which the pig moulds are made, and which are filled from the blast furnace through a sow.

Pig Boiling. — The modern process of



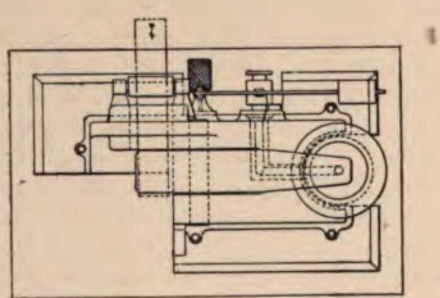


Fig. 48.—Hydraulic Pig-Iron Breaker.

puddling for wrought iron, in which the decarbonisation is effected by the oxide of iron in the fettling spread over the bottom of the reverberatory furnace. The term relates to the appearance of ebullition due to the escaping of the carbonic oxide generated below the surface of the metal. It is also termed *wet puddling* to distinguish it from the older method, in which sand bottoms were used, the term wet relating to the stratum of liquid cinder. It was the invention of Mr Joseph Hall, the founder of the firm of the Bloomfield Iron Works, Tipton, Staffordshire. *See* **Puddling.**

Pig-Casting Machine. — *See* **Casting Machine.**

Pigging Back.—To pig back signifies the recarbonisation of open-hearth steel, by the addition of pig iron, to bring back sufficiency of carbon to the charge.

Pig Iron, or **Pig.**—The commercial form in which cast iron is supplied by the smelters to the founders. It derives its name from the fact that the pig moulds are arranged in series from a long main feeder, the *sow*, which is run from the blast furnace. The moulds are in open sand. The section is that of the letter ⌂, but solid. The length is about 3 ft. and the weight about 1 cwt. each.

Pig is graded according to the quality, as indicated by the appearance of the fractured surface. It ranges from grey to white, as Nos. 1 to 8, or 10; or, as is now general, from 1 to 4; grey or foundry irons, and No. 4 forge pig, and also mottled and white.

In 1791 the quantity of coal consumed at Dowlais in making a ton of pig averaged 8 tons 1 cwt. A furnace turned out only 20 tons of pig in a week, and this was the average for the kingdom. By 1831, 3 tons of coal only were used, and the furnace output had increased to 78 tons. In 1859 the consumption was $2\frac{1}{2}$ tons, and output 137 tons per furnace. In 1896 the coke consumed was 19 cwt., equal to about $1\frac{1}{2}$ tons of coal per ton, and the output was 1,600 tons per furnace per week.

Pig-Iron Breaker.—A machine for breaking pig into short lengths for remelting in the cupola. In small foundries it is broken with a sledge, or by throwing a pig across the edge of another on the ground. One type of machine is operated by a treadle with a falling monkey. Another class of machine is shown in Fig. 48, by Bopp & Reuther of Mannheim. It is

operated by pressure water, a ram pushing a lever, the short arm of which breaks the pig, which is fed under the lever on a roller.

Pile-Driving Machines.—Machines for driving piles are derived from the old ringing engines. In these the monkey is held and pulled up by a single rope. From this rope other smaller ropes depend, each of which is pulled by one man, and each let go simultaneously. The lift is limited to a maximum of about 4 ft. The driving is carried on in spells of a few minutes, with intervals for rest. The weight of the ram or monkey does not exceed from 4 to 8 cwt. For each 40 lb. weight of ram one man is allowed.

Hand Machines.—In the hand pile-driver proper the ram is hoisted by a single purchase crab situated in the base of the timber framing, and having a rope or chain coiling round its drum leading off to the ram. When the latter is lifted to the height required it is disengaged by means of a catch, and so falls. The catch is pulled by a cord hanging from a lever, which with the catch forms a bell crank. The ram slides against the face of the uprights, or *leaders*, which are faced with iron ways. The weight of the ram may range from about 10 to 25 cwt., and the height of the framing from 25 to 40 ft.

Fig. 49 illustrates a 10-cwt. hand pile-driver by Youngs of Birmingham. It is a good

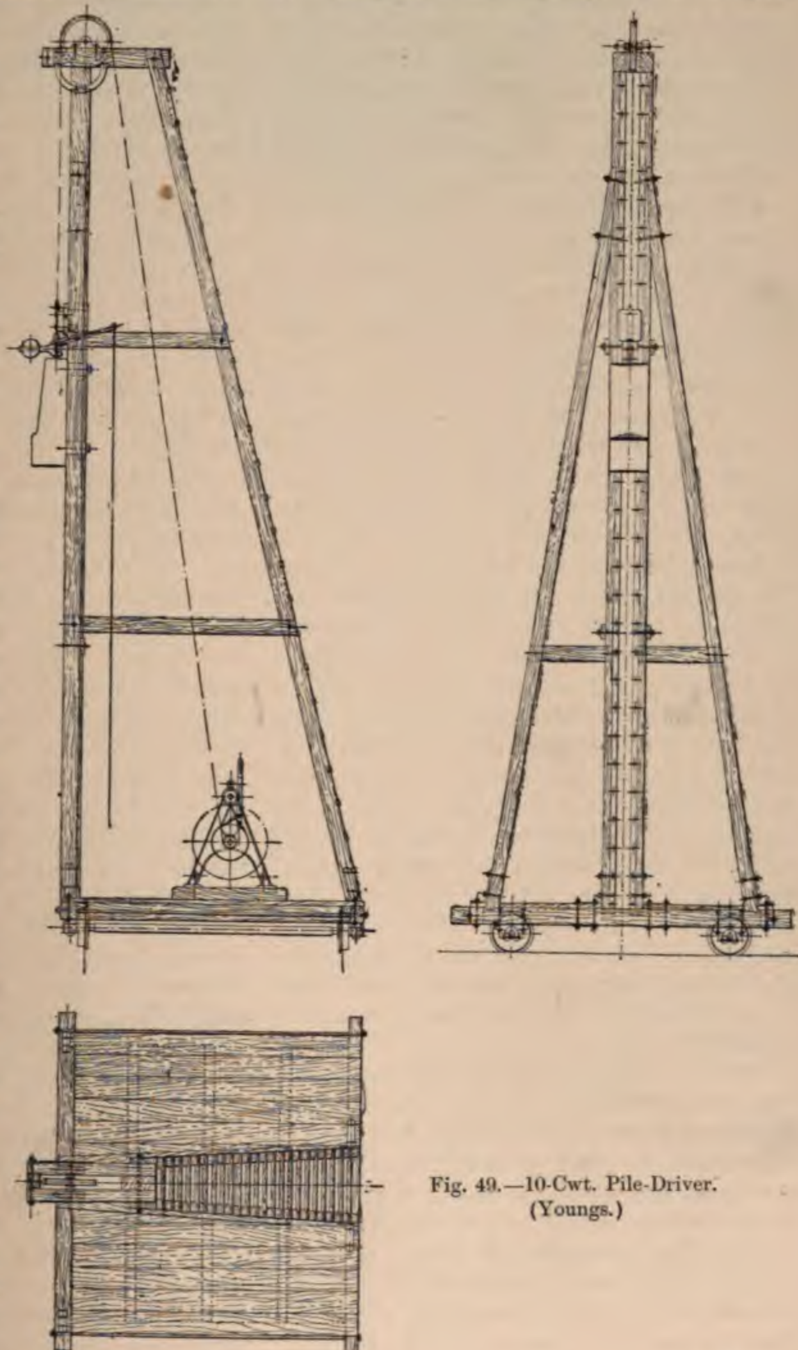


Fig. 49.—10-Cwt. Pile-Driver. (Youngs.)

example of a self-contained timber framed structure. The crab, the ram, catch, and hand rope for releasing the same are all clearly shown, together with the other details, so that a detailed description would be superfluous.

Power Machines.—The intermittent action of the hand machines was adopted in the earlier steam-power machines, the chain being lowered after each blow to hook on the ram afresh. Several pile-drivers have, however, been designed in which the chain runs constantly in one direction for lifting, and the ram is attached to and released from the running chain. In one of these an endless pitch chain passes over sheave pulleys at the top and bottom of the leaders. It also passes over a pitch chain wheel on the engine shaft, whither it is directed by suitable guide pulleys. A hole is cored through the ram, and a sliding bolt at right angles with the longitudinal hole can be made to engage with any link of the chain on pulling a cord which is attached to one end of a lever, which, with an eccentric, actuates the bolt. Release is effected by the attendant pulling at the opposite end of the lever, or by fixing a stop at any height on the leaders for the lever to come in contact with. The pitch chain is driven by a pair of oscillating engines, and the same engine shaft which carries the pitch chain wheel drives a long chain drum, used for pitching the piles, by means of an ordinary chain which passes over a pulley in the top of the framing. A sliding clutch is used for making and breaking connection between the engine shaft and the chain wheel, or the drum. This avoids the need for a separate winch for setting the piles. This, in common with some other makes, has provision for inclining the leaders from the perpendicular, so that piles can be driven with a batter.

When the ends of piles are driven lower than the bottoms of the leaders, a *dolly* is sometimes interposed between the monkey, and the pile. This is a piece of balk of about the same cross section as the pile. The objection to this is, that it absorbs about half the energy of the blow. The alternative is to fit telescopic leaders, slid upon the leaders of the main framing, and adjusted to the depth of the pile. The ram descends on these below the framings.

Lacour's Steam Pile-Driver.—This is a design in which the ram is a cylinder moving over a fixed piston, the lower end of the piston rod resting upon the pile, and forming the point of resistance for the upward movement of the cylinder. This is effected by steam introduced between the top of the piston and the cylinder cover. When the cylinder is lifted to its maximum height (or to any other height regulated by the attendant) the exhaust is opened, and the cylinder falls by gravity on the head of the pile. A three-way valve controls the steam and exhaust through one passage in the cylinder cover, and a flexible tube conveys the steam to the monkey at its varying heights. One hole near the bottom of the cylinder permits the escape of condensed steam from below the piston, another allows pressure steam to escape, in the event of the steam inlet being opened too long.

Whittaker's Steam Hammer Pile-Driver.—This resembles Lacour's in the lifting of the cylinder, but differs in details. The steam is admitted through a long telescopic pipe lying parallel with the ram, and which slides with the ram. The latter is guided by rollers at top and bottom behind the leaders. In some designs the blow is delivered by steam pressure assisting the action of gravity.

New Southgate Pile-Driver.—This design only resembles the previous ones in the fact of the lifting of the cylinder ram by steam pressure. The piston rod is formed in two portions, Fig. 50, the solid portion A, the end of which rests on the pile (and which is forged in one with the piston) and a hollow portion B extending out through the cylinder cover. Through it the steam is admitted. This contains the steam inlet ports *a* to the cylinder at its lower end, where it joins the piston, and at the upper end a piston valve C, through which the admission of steam to the tube takes place. The piston valve is operated by a lever D opening it when the lever is pulled in one direction, and allowing it to close by the steam pressure when the lever is pulled in the opposite direction. This was fitted by the New Southgate Engineering Co. not only to ordinary fixed machines but also to trench, and to portable machines.

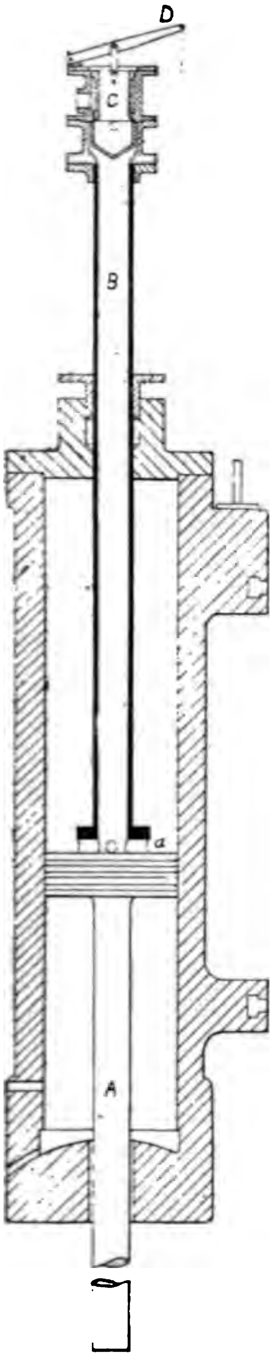


Fig. 50.—Pile-Driver. (New Southgate Engineering Co.)

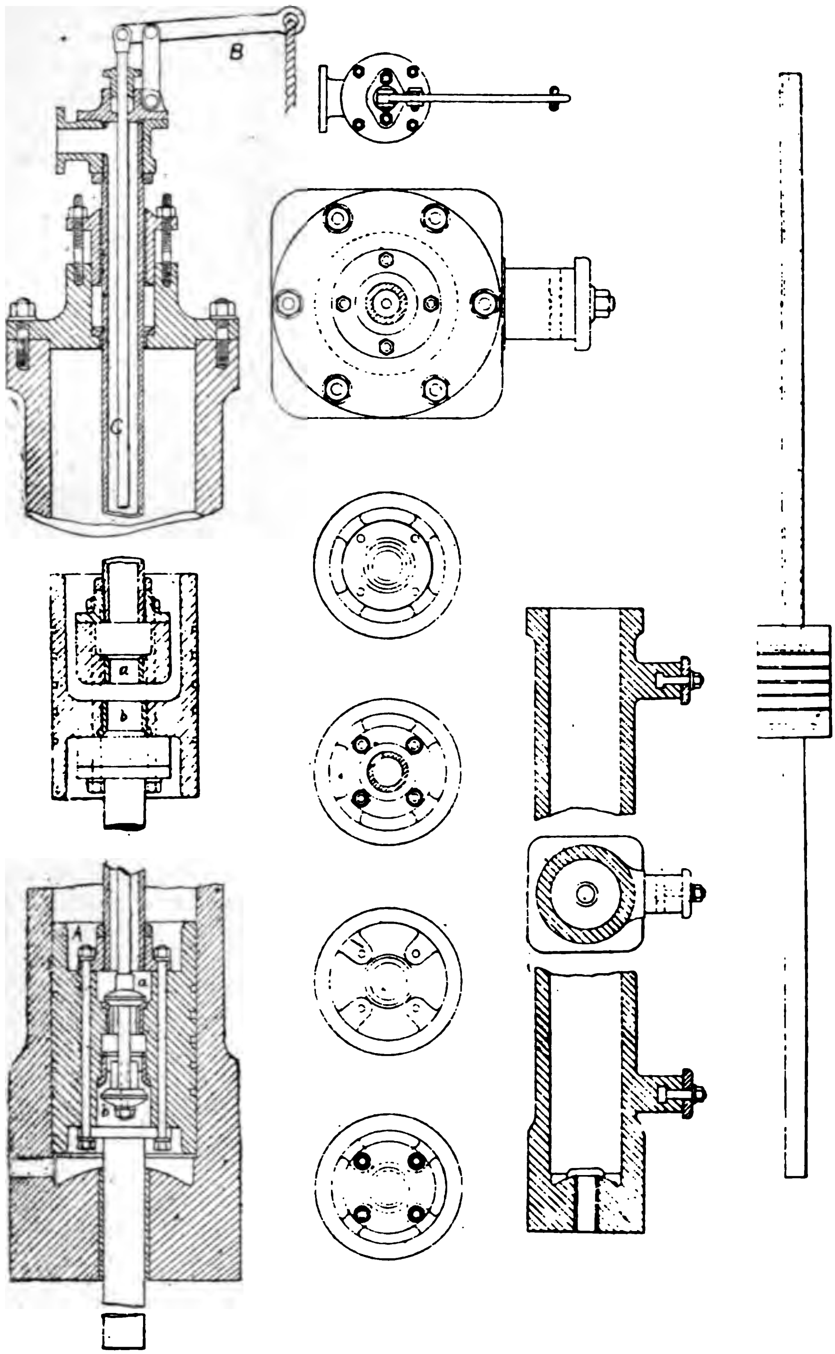


Fig. 52.—Pile-Driver. (New Southgate Engineering Co.)

Fig. 51, Plate VI., illustrates a machine working at Folkestone on sea-defence works. The piles were driven on a batter, and were 12 in. by 12 in. by about 20 ft. long, and driven into hard blue gault. About 10 ft. each of fourteen piles were driven each day, the monkey weighing 25 cwt., and giving fifty-four blows a minute with about 5 ft. to 6 ft. drop.

This design has been modified in the firm's latest pattern, illustrated in Fig. 52. In this the steam and exhaust valves are placed in the piston A, *a* being the steam valve, *b* the exhaust. The lever B and rod C actuate the steam valve for opening and closing, the exhaust valve opens automatically for the down stroke. The exhaust steam escapes through the bottom of the monkey into the atmosphere. The exhaust steam accelerates the descent of the monkey, and there is a saving in steam, as the hollow piston rod is not emptied at each stroke. The various sections give full details of the construction.

Trench Machine.—This, made by the same firm, is used for driving piles in parallel, and both simultaneously when sheet piling is required for retaining loose soil, and when foundations have to be got out for buildings, and spaces for sewers. It comprises a wooden framework mounted on a carriage with wheels, and having two sets of leaders at the front of the carriage. These are attached to cross pieces fixed at intervals up the front of the frame, to permit of the guides being moved across the front of the frame to enable piles to be driven at various distances apart.

Travelling Pile-Driver.—In this machine by the New Southgate Engineering Co. the leaders are carried on an adaptation of a steam crane design with a revolving bed on a bogie truck for a railway gauge. The leaders occupy one end of the revolving bed, the boiler and ballast tanks the other, and the engines midway. The leaders fold down to permit of railway transit. There are two pairs of engines. One set is used for slewing, and also for lifting the monkey to the top of the piles, and for hoisting the piles into position in the first place. The second set is used for travelling only. Pile-drivers of this class require the aid of three men. They work at a boiler pressure of from 60 to 80 lb. per square inch; fifty blows a minute is a good record for the best machines. The best result ever obtained was an average of sixty-three blows per minute, with a 4 ft. 6 in. drop; this was driving concrete piles.

Electric Pile-Drivers. — The arguments in favour of the substitution of electric driving for that of steam in cranes and other machines apply with equal force to pile-drivers. Given the generating station, the current can be carried to any point, and the use of steam pipes, boilers, and engines avoided. In the electric pile-driver by the New Southgate Engineering Co. the hoisting is done by an electro-magnet which attaches itself to a planed face on top of the ram, when current is switched on. The magnet is connected by wires to a motor on the hoisting crab, and is worked by a switch from the crab. When current is switched on, the winch lifts the magnet and ram to the required height. On switching the current off, the ram is released, and falls. The magnet follows, ready to be switched on when the blow has been delivered. The electric winch is continually in motion. The barrel shaft is fitted with a large right and left-handed friction cone clutch which is operated through the centre of the barrel shaft by electro-magnets.

Some pile-drivers are mounted on turntables to permit of driving piles at any radial position. Others have provision only for driving at right angles. The common hoisting engine is used for operating a pile-driver. The American hoists, with two, four, or six drums, are used largely for the same function, and the ropes may be led off to work several drivers simultaneously.

With regard to the use of the term "monkey," and "ram" it has been pointed out by Mr Perry F. Nursey, *Engineer*, vol. xciv., p. 285, that the former is incorrect, and has crept in without the justification of the usage of engineers. He says that the snatch hook of the pile-driver is the monkey, and the weight is the ram, and that the term "monkey engine" was applied to the original pile-drivers that displaced the "ringing engines," the application doubtless being derived from the monkey-like action of the snatch hook, which was the only

Fig. 51.—Pile-Driver in Operation at Folkestone.

Fig. 59.—Pillar Drilling Machine. (Ludw. Loewe & Co., Ltd.)

Fig. 60.—Pillar Drilling Machine. (Sir W. G. Armstrong, Whitworth, & Co., Ltd.)

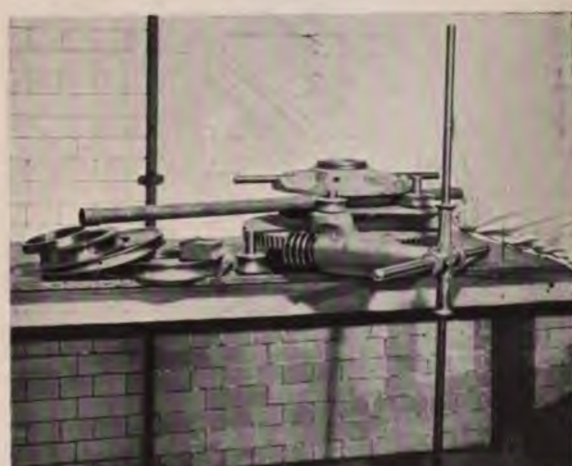


Fig. 61.—Pipe-Bending Machine. (J. Barker & Co., Ltd.)

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new feature and which displaced the numerous ropes of the ringing engine.

Hydraulic Pile-Driving.—This is a method adopted when the soil is gravelly or sandy, into which piles do not drive so readily as into clay. A jet of water is driven down into the soil below the pile, softening and disintegrating it, into which the pile sinks either by its own weight, or by a dead loading. The water is brought in at the foot by means of gas piping with a short return nozzle, and coming underneath the pile. The ends are not generally pointed in this case.

Piles, Pile-Driving.—Piles are used for making an artificial foundation in untrustworthy soil, as in clay, gravel, sand, loose boulders. They may form the actual basis for foundation, the structure resting directly on them, or they may simply enclose concrete or masonry, the actual foundations. When, as in the latter case, the piles are driven in contact, the term *sheet* piling is applied. Piles may be driven vertically, or inclined—with *batter*.

Theoretically there should be no difference between the effects of a blow delivered by a light ram or monkey at a great height, and a heavy ram from a lesser height, the product of mass × fall being the same. But experience shows that the latter is more efficient. A light ram, falling from a good height, produces vibration and jar, which tends to split the piles. Another point is, that the driving must be uninterrupted. If a pile is left partly driven over-night, the resistance to driving is increased about threefold.

With regard to the limit of driving, opinions differ greatly. A pile is supposed to be driven sufficiently when it will not sink more than from $\frac{1}{10}$ in. to $\frac{1}{4}$ in. under a given number of blows. Rankine gives as a test, a depression of not more than $\frac{1}{5}$ in. by thirty blows of an 800 lb. monkey falling 5 ft., or mechanical energy of 600,000 ft. lb. per inch.

The sustaining power of piles is generally considered to bear a relation to the limit of driving, for if a given blow will only sink a pile through a minute distance, it seems reasonable to suppose that it would be an indication of the load which it should sustain without further yielding. Rules are given by Rankine and others based on the depression of the pile in feet by the last blow. But they differ much. For, as Trautwine points out, "No rule can apply correctly in all positions. The ground itself between the piles, in most cases, supports a part of the load; although the whole of it is usually assigned to the piles. Again, in very clayey soils, there is greater liability to sink with the lapse of time, in consequence of the admission of water between the pile and the clay; thus diminishing the friction between them. The less firm the soil, the more will the piles be affected by tremors; which also tend in time to cause sinking. In some cases this sinking will not be that of the piles settling deeper into the earth around them, but that of the entire compacted mass of piles and earth into which they were driven settling down into the less dense mass *below* them."

Trautwine's own approximate rule is: "Multiply together the cube root of the fall of the monkey in feet, the weight of the monkey in lb., and the decimal ·023. Divide the product by the last sinking in inches + 1; the result is the extreme load in tons which the piles should sustain. A factor of safety as low as two may be taken in some cases if the piles are thoroughly driven into firm soil, but not more than one-sixth if driven into river mud, or marsh, and if subject to tremors, not more than half the above." The cross section and length of a pile are not taken into these calculations, for the resistance of a pile is the real measure of its capacity to sustain stress, and this is not affected by variations in dimensions or weight. A good formula for the working load on piles is the following, originally due to the *Engineering News*:—

Bearing power of pile =

$$\frac{2 \times \text{weight of ram} \times \text{height of fall in feet}}{\text{last penetration in inches} + 1}.$$

The great differences which are found in soils affect the penetrability of piles. Sands, clays, and gravels are as a rule readily pierced, but cases occur in which piles cannot be driven beyond 5 or 6 ft. in depth. A mixture of mud with sand and gravel facilitates driving.

Piles are often driven with blunt ends, as it is found that they have less tendency to run

out of perpendicular than pointed ones. But for firm stony soil piles must be pointed. The points must be protected with shoes, of wrought

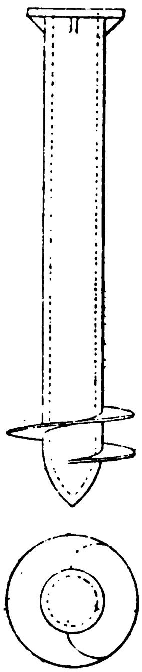


Fig. 53.

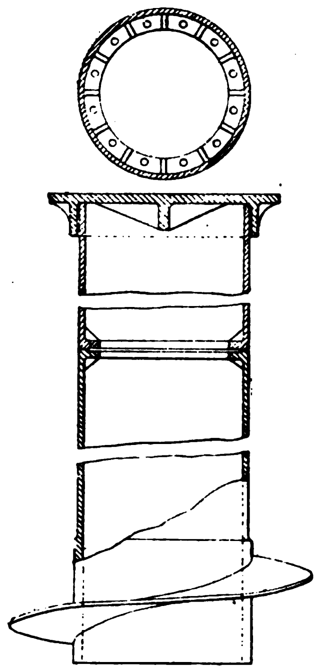


Fig. 54.

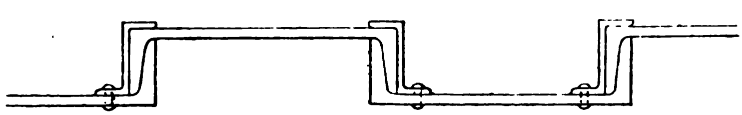
Cast-Iron Piles.

iron generally, which are spiked to the timber. The heads are prevented from splitting, with rings shrunk on. But the heads often split below the ring in hard soil, and crush badly, termed *brooming*. It may often happen that heads may have to be sawn off once or more, and rebonded on this account. Piles frequently have to be sawn off level under water. A special circular saw is used operated from above. *See* **Pile Saw**.

Materials of Piles—Timber.—Timber is used more than any other material for piles, because cheap, and under suitable conditions, very durable. Elm, oak, the deals, greenheart, and some of the Australian hardwoods are all commonly used for piles. Any timbers which resist the action of moisture, and the attacks of the *Teredo navalis* are suitable for piles. The timbers are generally square, but sometimes the rough boles are used. Ten to twelve inches square is a usual cross section, and lengths to suit the depths of the foundations.

Cast Iron.—Screw piles are often used in gravelly soil. They do not readily penetrate stiff clay. The screw is from 7 in. to 8 in. pitch, and comprises a single turn only. The edge is sometimes serrated. The pile end is pointed, Fig. 53, or blunt, Fig. 54. The pile is turned in with heavy worm gear. Capstan bars have been used, pulled by a rope from a winch. It is necessary when the ground is stiff to load the top of the pile with pig iron or other material, otherwise it will turn without screwing itself in. The screw lengths are not cast of the full length for deep piling, but make-up lengths are added as the depth increases, being bolted with flange connections, or sockets and spigots.

Steel Piling.—A good deal of piling has been used in America under the Friestedt patents, which cover a large number of designs. It is a sheet piling, composed of a series of interlocking steel rolled sections, as channels, beams, angles, and zeds, Fig. 55, so united as to be watertight except in very wet loose soil, in which some little packing is required. The claims made for this in cofferdam work are that double rows of sheet piling, inner and outer, are rendered unnecessary, a single set of piling sufficing to enclose the space. The interlocking is shown



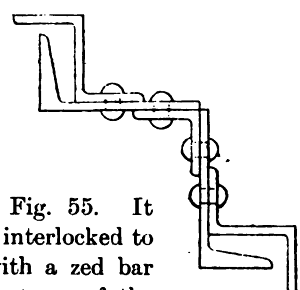


Fig. 55.—Friestedt Piles.

in its essentials in Fig. 55. It comprises a channel interlocked to a similar channel with a zed bar riveted thereto; the taper of the inner faces of the channel flanges renders the joint watertight. A beam or joist is also combined with a channel. Combinations of angles and zeds are also made, and some others. The

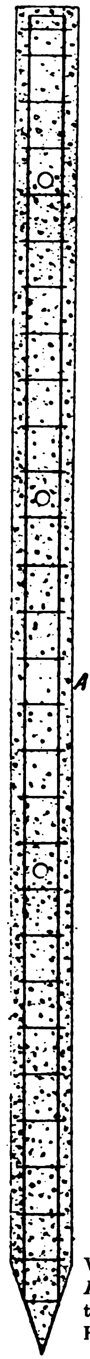
sections are driven by a monkey, as in other piling, and exceptionally long lengths are made up by jointing. Corners are made up in various ways, one being seen in Fig. 55.

Concrete Piles.—The ravages of the *Teredo navalis* in sea piles cause rapid decay of timber, an objection from which piles of concrete, Figs. 56 and 57, are free. These are steel rods arranged in skeleton-like fashion, around which the concrete is moulded, and in which the rods are wholly encased. The shoes, also of steel, are built into the moulded piles. The Williams pile is shown in Fig. 56, A, B, and in Fig. 57, with a steel shoe. There is no limit to the length in which such piles can be made, and thus horizontal joints are avoided. Sheet piling differs from the ordinary piles in the shape of the shoes, which are wedge shaped in the sheet piles, and in the formation of a semicircular groove down the abutting edges of the piles. Into the latter fine concrete is filled, as in jointing concrete blocks for sea work. These piles are made in the Hennebique system, Fig. 56, C, by enclosing a series of iron rods running longitudinally, and bound with cross trees in concrete.

Pile Sawing Machine.—A machine for cutting off the heads of piles level after they have been driven into place. A machine of this kind, made for use on Dover Pier by Messrs Isaac Hill & Son, is attached to the pile by a belt and clamp, by which it is swivelled round the pile after a cut. Three cuts are required, with three settings, to sever a pile, the saw cutting towards the centre of the pile. The saw is of the flush side type. It is driven by manual power, handles being fitted to two flywheels, and the drive taking place through spur and bevel pinions and wheels, forming double gears. It is lifted by an eye in a cross-bar over the machine.

Pile Screw Patterns.—Pile screws seldom form more than one revolution, or one and a half revolution of a circle. They are large in diameter, standing out from the body around which they are fitted to a distance of from about 8 in. to 12 in. As the screw blades are thin, there is only one way in which they can be fitted, namely with the longitudinal direction of the grain standing perpendicularly to the body. The body therefore is turned first, and the blade fitted to it, and turned subsequently.

Fig. 58, A, shows a body before the screw is fitted. This is jointed in the middle plane. It is sometimes made in solid stuff, but the better way is to lag it up as shown, similarly to pipe and column patterns. This is advantageous, not only because it will retain its first accuracy longer, but



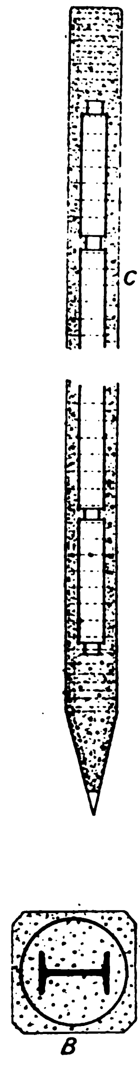


Fig. 56.—*A.* Williams Pile. *B.* Enlarged Section of ditto. *C.* Hennebique Pile.

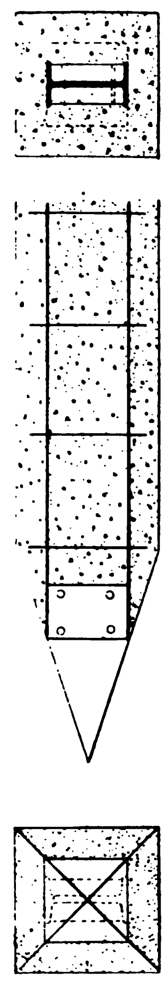


Fig. 57.—Williams Pile.

chiefly because the screw blade has to be screwed from within, and it is better to have the internal flat faces of the lagging to screw against than to bore down from the joint face for the insertion of the screw heads. The manner of lagging is clear from the figure, and will be readily understood. The cross-bar at the pointed end is a solid block, to permit the turning down of the taper. Elsewhere the cross-bars are narrow.

The screw blade has to fit in grooves cut in the body. This is necessary to the retention of these blades in place, for they have to be at the root will give the width of the groove to be cut. Or, if a piece of paper C having the dimension *c*, equal to the circumference of the body, and having diagonal lines drawn to correspond with the pitch *p*, with other lines parallel therewith to give the width of the groove, is glued round the body, then these lines will afford a correct guide for the cutting-in of the groove as at A. The latter method is the quicker of the two, otherwise there is little to choose between them. The groove is sawn and chiselled round, using a templet for its depth, Fig. 58, E.

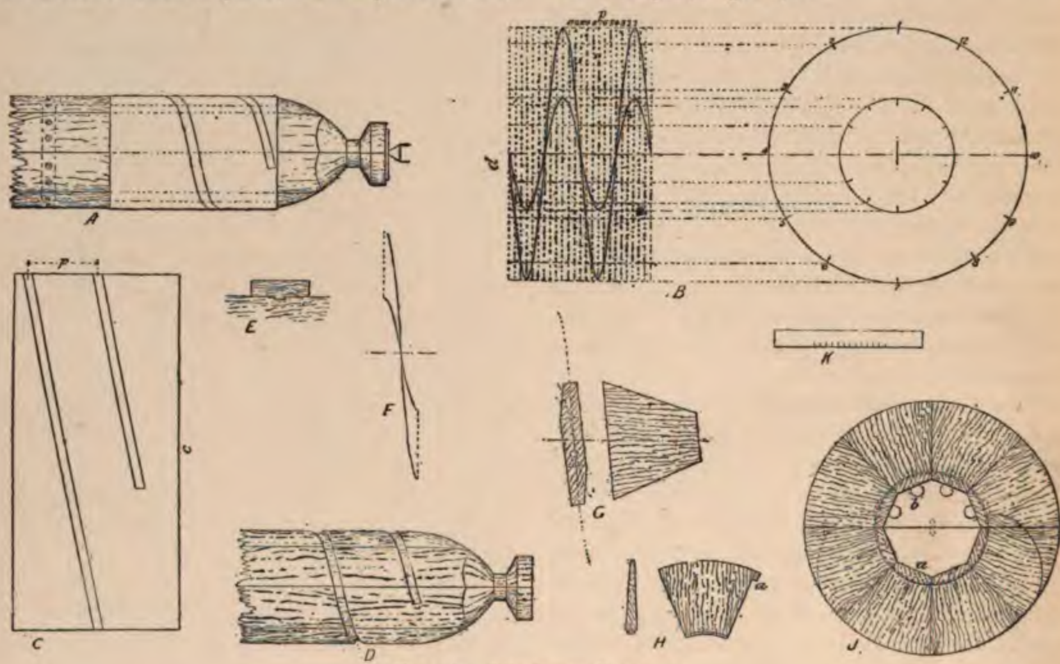


Fig. 58.—Pile Screw Patterns.

left behind in the mould after the withdrawal of the body therefrom, and taken out subsequently in segments. The grooves are shallow, —about ¼ in. only in depth. They are of course of the same pitch as the screw blade. They are marked out either by lines of equal division, or by a paper templet. Thus, if the diameter *d* of the body, and the pitch *p* of the blade are divided out into any number of equal divisions, as in Fig. 58, B, a line drawn through the points of intersection will delineate the screw, and another line marked parallel with that at a distance away equal to the thickness of the blade

The fitting of the blade segments has to be done carefully in two ways. They must bed closely in the groove to prevent them from movement during moulding. Also they must be roughed out sufficiently large, and of such a shape as to permit of the screw thread being cut from point to root. As the angles at root and point are very different, F, the segments must be cut out of a sufficient thickness to include both. The plan, Fig. 58, G, illustrates this. Also, during the fitting, note must be taken to maintain the segments in such a position that the top ends will be at the correct

angle approximately for the tip of the thread. This is tested by a set-square raised up from the body against the face of the segments, at the edges of each. This will indicate approximately the correct position, because the centre of every screw thread must stand perpendicularly on its base. There will be six, or, in a large screw pile, eight segments to the circle. These will not be united to each other, because they cannot then be got out of the mould, owing to the friction of the sand in the large twisted blade surfaces. They are, however, retained in position relatively to each other with a tongue fitting, H, at *a*. And they are screwed to the body from within it. As they have to be moulded many times, wood screws would not hold in end grain, and plates are therefore let into the blade segments to receive thumb-screws, J, wood screws being shown at *a*, and alternatively thumb-screws at *b*.

The pattern will of course have to be taken apart in the joint to permit of the insertion of the screws, after which it will be returned to the lathe for the turning of the top of the screw blade. This must be done carefully, because of the narrowness of the surface, and dogs must be inserted at the joints of the blades with each other, at the sides, to prevent possible risk of their flying asunder.

The best way to turn the tips is to set the rest by measurement from the centre of the lathe, and so, by turning the wood parallel with the rest, the parallel diameter of the work will be assured, measurement by calipers not being practicable. A sharp gouge must be used, held rigidly, and light cuts taken. A firmer chisel may be used to impart the finish.

To mark out the thread on the tips some care is necessary. In the first place, the pattern must be taken from the lathe, and lines scribed in the joint face on the centre of the screw blade perpendicularly to the body. These are produced on the outside of the turned tips, and then the pattern is put together again and returned to the lathe, and these lines carried round. They give now the pitch on the tips, which corresponds with the pitch on the body. The twist of the screw will be got from intersecting lines, the use of paper being impracticable. The distance between the pitch is divided directly from a strip of wood laid on the rest, K, from which lines are struck on the tips during the revolution of the lathe. Then the circumference is divided out into the same number of parts, and lines marked from a straightedge laid on the rest. The screw thread is marked through the intersecting points with a bent steel laid upon the turned tips, using a scriber point.

To work the blades the pattern must be taken from the lathe and the wood screws withdrawn in the joint face, leaving each blade to be shaped separately. The shaping is done with planes, after roughing off the majority of the material with paring gouges. The jack plane will be used for reducing nearly to size, but in consequence of the twist of the blade the jack plane is too wide for finishing, for which a rebate plane is used. Every section must be planed absolutely straight from body part to tip. The rounding of the edges and the cutting of the entering and leaving edge is done subsequently. Blades made in this way will deliver freely from the mould, without any twisting out, if taken in sections as fitted to the body.

Piling.—The welding together of iron bars in piles for the rolling of bars, sections, and plates. Piling is done in the case of the smaller bars to improve the quality of the product by the work done upon it. Thus, merchant bars are piled from puddled bars, and the superior qualities are produced by a second or third cutting up, and piling. Sectional forms, as angles, tees, &c., and formerly rails, are piled to produce the varied sections required.

In piling for plates, slabs are placed at top and bottom of the piles of bars, and the whole is arranged so that the fibre crosses and re-crosses at right angles. The piles are raised to a welding heat in reheating furnaces, and then consolidated by hammering and rolling. Piling is also practised in engineers' smithies, where it is termed *fagoting*. Odds and ends of scrap are welded, and drawn out by hammering to produce *fagoted scrap*, which is exceptionally tough and strong, and is used for high-class work. Cranks are often made from this product.

The objection to piling is the risk of en-

closure of oxide and dirt—a sandwich of iron and dirt. Steel, which is free from these evils, has to a large extent displaced piled iron for all except some of the smaller sections, and for some classes of work, light forgings chiefly, for which good iron is preferred.

Pillar Drilling Machine.—There are many types of drills which have an upright pillar as the basis of the frame, forming a means of attaching a base-plate and an adjustable table. The bearings for the drill spindle are either cast solidly with the pillar, in the case of small machines, or the lower bearing is movable, sliding upon flat ways, in order that the bottom end of the spindle may be adequately supported at all times, close to the work. The spindle has a certain amount of movement in this bearing, so that the feed may be imparted by means of rack and pinion through hand or power. The base-plate is tee-slotted to attach work by, while the table, of circular form, is secured in a split bracket embracing the circular pillar, and raised or lowered thereon by rack and pinion. The rack is concaved to fit the curve of the pillar, so that the whole table arrangement can be slewed around out of the way. An extension of the pillar at the rear provides means of carrying the lower driving cones, with fast and loose pulleys, and the upper cones, connecting, with or without back gear, through a bevel gear to the spindle, or a sleeve upon it. The terms *Upright*, or *Column drill* are also used in connection with these machines.

Fig. 59, Plate VI., represents a typical pillar drill which embodies the sliding spindle head, with a hand and a self-acting feed to the spindle sleeve. The rack for elevating the table is of helical form. A good many points mentioned may be noted in this illustration.

Another class of pillar machine, shown in Fig. 60, Plate VI., has a stiff boxed-up column, and the drill spindle slides through a sleeve. The feed is given either by hand wheel, and worm gear driving a pinion which racks an extension of the spindle up or down, the same effect being produced also by the belt cones; or the spindle may be pulled down quickly for light work by the long counterbalanced levers at the top. The table has compound slides.

Pillar File.—*See* **Files.**

Pillar Milling Machine, or **Pillar and Knee Machine.**—Generally understood of the type which is described under **Universal Milling Machines**, with horizontal spindles. But many of the vertical machines comprise a pillar and knee to carry the tables.

Pillow Block.—A plummer block. *See* **Bearings.**

Pilot.—Something which serves as a guide to something else. Pilot pins are used to locate centres and bearings. A pilot light is one that ignites a larger light.

Pin.—A fastening or pivot which is not threaded, but which is secured by other means than by a screw thread, as by a split pin, or a cotter. The pin is usually furnished with a head at the end opposite to the split pin, or cotter, but sometimes it may be plain, and secured similarly at both ends. Pins fail by bending, or by shearing, the method depending on their length and the support afforded. A tapered circular pin is used as a key for light work, such as small gear pulleys, and milling cutters. It is not so liable to cause cracking of the boss or cutter as a key of square section would be.

Pin Drill.—*See* **Drill.**

Pine (*Pinus*).—A term applied to a large number of species which are of great value to engineers. They belong to the natural order Coniferæ. They are characterised by softness of wood, straightness of grain, resinous properties, and generally large dimensions. They are found mostly in the North Temperate Zone in Europe, and North America. The firs are imported from the Baltic, the yellow, white, red, and pitch pines, and white and black spruce from America.

Pin Gear.—*See* **Lantern Gear.**

Pinion.—A toothed wheel of small diameter. The term is relative only, being applied to the smaller wheel of a pair, or the smaller wheels in a train.

Pinny.—Signifies the presence of hard specks of metal in wrought iron or brass. Also the choking of a file with particles of filings.

Pin Vice.—A very small hand type of vice, having a hollow handle, through which lengths of wire or rod may be passed, or pins, &c.,

held with their shanks projecting into the handle. It is a very convenient tool for light metal workers, and enables such work as the above to be held more securely than in the bare hands. Some types have the jaws formed by splitting down the metal, and fitting a screw and wing nut; another class have toggle jaws, pivoted near the centre to a block, and opened or closed by a coned neck, which is forced to and fro by screwing or unscrewing the handle, upon which the cone is made, the effect being to move the other ends of the levers, where the jaws are situated inwards or outwards, and so grip or release the work.

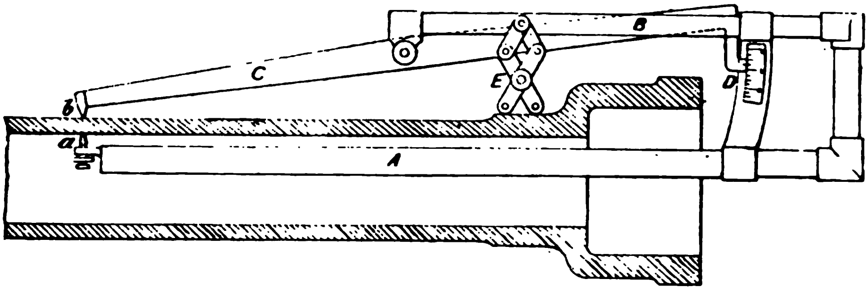


Fig. 62.—Pipe Calipers.

Pipe Bending.—Copper and lead pipes are bent cold, those of wrought iron and steel are heated. Before bending, it is necessary to prevent wrinkling in the internal angles by filling the pipe. Melted resin or a very fusible alloy are used in cold bending, but sand when pipes have to be heated.

Pipe Bending Machines.—These are designed to avoid the tedious bending done by hand with the tongs, while the pipe is held in the vice, or in a board. Some machines employ hand leverage only, but for the larger sizes, screw, or hydraulic pressure is adopted. The curve is produced either against templets; or three rollers, two being adjustable to different centres, the third being pressed by the ram midway between them. The adjustments give different radii, on the same principle as those of plate bending rolls.

The Kennedy pipe-bending machine, Fig. 61, Plate VI., employs a loose ring or roller, concave-edged, and of a diameter corresponding to the intended radius. This ring is slipped over a screwed mandrel fixed in the machine base, and a top flange is screwed down to retain the pipe. The latter is then bent by revolving the machine with worm gear, rollers being placed at the sides to prevent lateral motion of the pipe. A series of differently sized rings are provided to accommodate various pipes and radii.

Pipe Calipers.—Long-armed calipers used

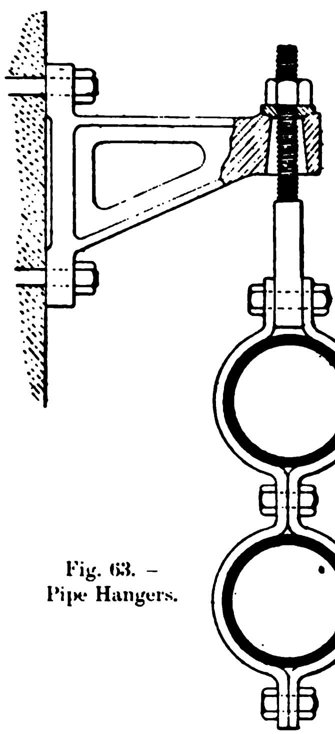


Fig. 63.—Pipe Hangers.

for measuring the thickness of a pipe or column several feet away from the ends. In the calipers designed by Mr F. Clarke the construction is as follows:—Two parallel bars, Fig. 62, A, B, connected rigidly at one end form the frame,

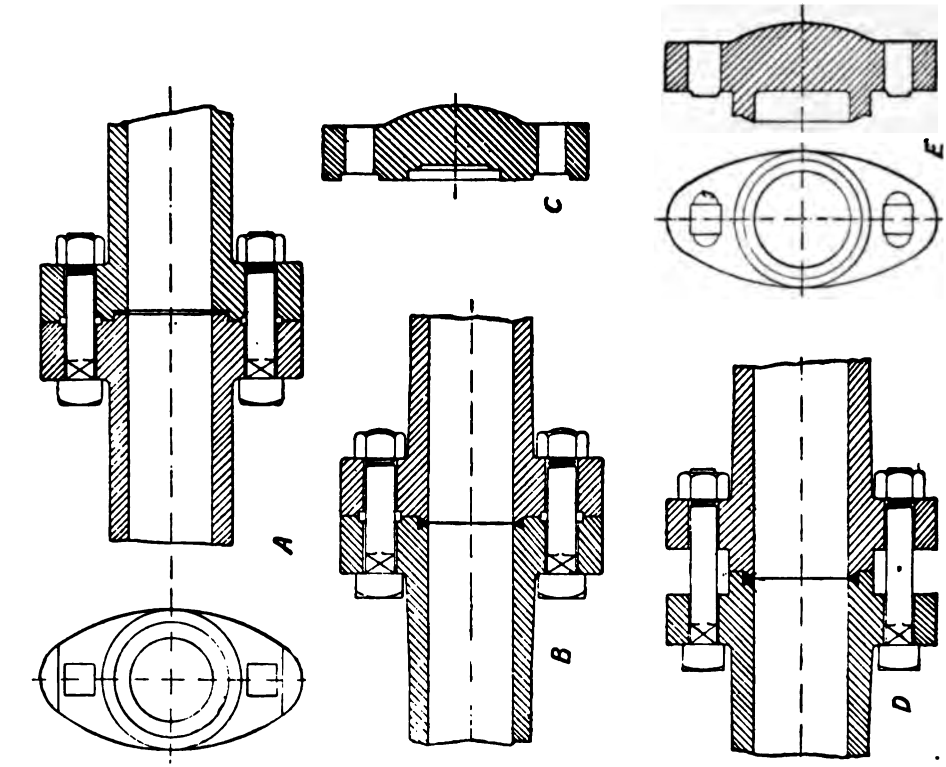


Fig. 65.—Hydraulic Flanged Joints.

A. Plain Registered Joint. *B*. Ditto with Vee Recesses. *C*. Blank Flange. *D*. Ellington Joint. *E*. Blank Flange.

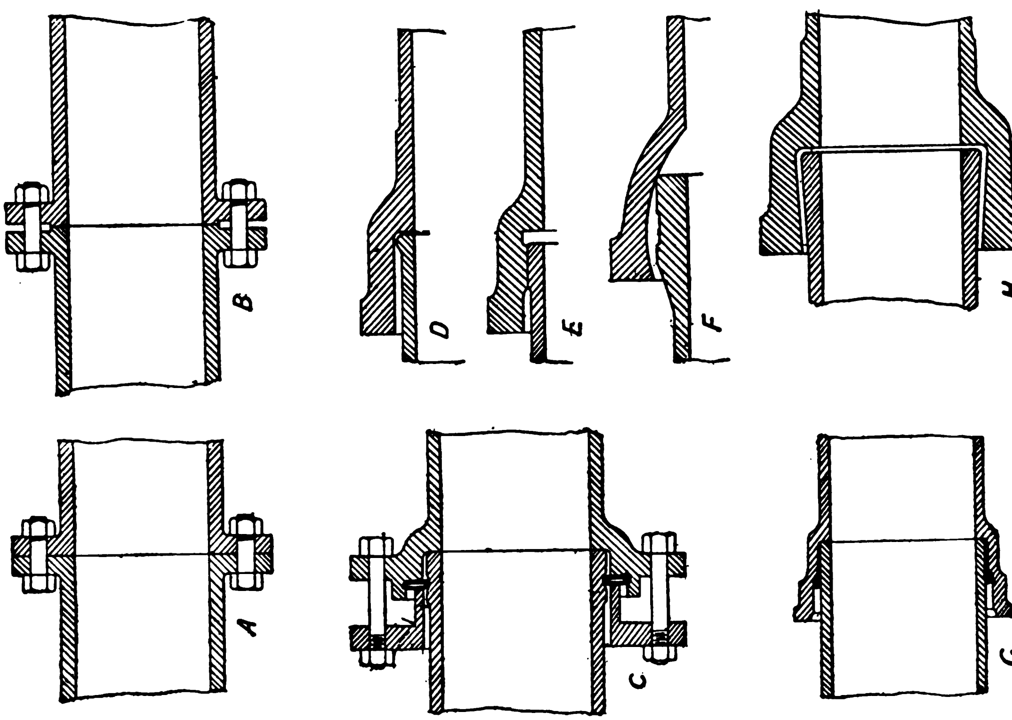


Fig. 64.—Flanged and Socketed Pipe Joints.

A. Plain Flanged Joint. *B*. Joint made with Narrow Annulus. *C*. Gland Type of Joint. *D*. Common Socket and Spigot. *E*. Ditto Turned and Bored. *F*. Flexible Joint. *G*. Socket Joint Stemmed with Ring. *H*. Tapered Socket Joint.

one bar being shorter than the other. A contact piece *a* is screwed in the longer arm at its termination. The other contact piece *b* is on the end of a lever C pivoted on the shorter arm. This contact piece is rigid, but the other is adjustable with a screw and lock nut. The opposite end of the lever has a projection which moves over a graduated scale D, which may be plain, or made as a vernier. A support E is provided on the short arm to prevent spring of the apparatus, and ensure a true reading.

Pipe Coverings.—*See* **Non-Conducting Coverings.**

Pipe Hangers.—Loops of iron or steel rod dependent from overhead beams or brackets, Fig. 63, to carry steam and hydraulic pipes. They have some means of vertical adjustment, effected by a screw. If there is much vibration, lock nuts should be fitted. There are many methods of suspending the loops.

Pipe Joints.—These include many kinds, rigid and flexible, flanged or socketed, registered or not, suitable for steam or liquids, for high or low pressures. Most joints are absolutely rigid, the exceptions being few.

Flanged Joints.—These, Fig. 64, A, are made with plain abutting faces; or, for high pressures, often with registered or checked faces, Fig. 65, as in most hydraulic work. Plain faces are very seldom left rough as cast. When they are, the joint is made with a ring of plaited tar twine, or a washer of millboard, or indiarubber. Red lead mixed with oil into a thick paste helps to fill up interstices. A tar twine joint with red lead is used for many manhole joints. It yields to the pressure of the bolts, and so makes a close joint. But most flanges are faced. Between merely facing with a rough cut, and scraping there is a good deal of difference. A scraped joint is steam-tight at high pressures, without any insertion beyond a thin film of red lead in oil. A rough-turned joint requires an insertion of wire gauze, or indiarubber, or asbestos sheet, or plain canvas, or American cloth; smeared with a thin layer of red lead in oil in most cases. This is not necessary with indiarubber. The higher the steam pressure, the less red lead should be used, because of its liability to get blown out. On some narrow faces a ring of copper wire bent to overlap is suitable. Being squeezed by the tightening of the bolts it prevents leakage past it. Many flanges, instead of being jointed all over, have only an annulus next the bore in contact, Fig. 64, B. This saves much fitting and permits of making a good joint quickly. Sometimes the open portion is filled up with rust cement.

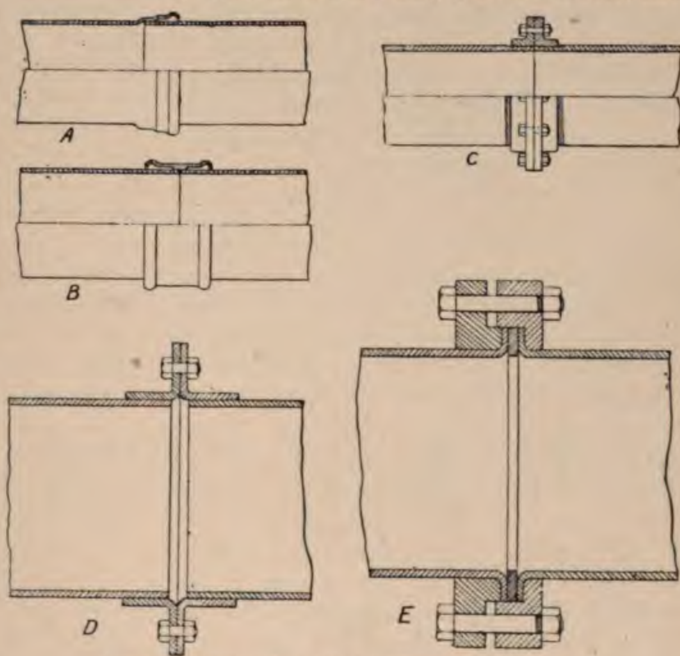


Fig. 66.—Steel Pipe Joints, Socketed and Flanged.
A. Pressed Socket. *B.* Thimble Joint. *C.* Screwed Flanges. *D.* Form of Flange for Riveting or Welding. *E.* Loose Flanges.

Joints are registered for high water pressures. There are several variations in the design. In some a plain recess is bored in one flange, Fig. 65, A, and a projecting annulus turned on the other to fit it. An indiarubber ring is inserted in the bottom of the recess, and being squeezed by the projecting portion by the tightening of the bolts makes a tight joint. Generally, however,

there is a register and vee grooves in conjunction, B, and an indiarubber ring of circular section is squeezed in the vee grooves by the tightening of the bolts. This joint is suitable for any pressures. In some cases the vee is

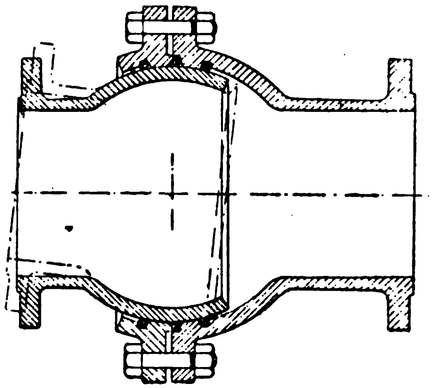


Fig. 67.—Flexible Pipe Joint.

recessed in one flange only, the meeting flange being left flat. These flanges are either circular or elliptical in shape, the first for the larger, the second for the smaller pipes. The bolts are turned and fit in drilled holes. The number of bolts and the thickness of the flanges increase with the pressures and stress on the pipes. *See* **Flanges**.

The methods of union are either screwing, riveting, or welding. Screwing, C, is only adopted for cast-iron flanges for moderate pressures, for high pressures riveting or welding are substituted. The flanges should be shrunk around the pipes before riveting is done. Sometimes narrow rings only are welded, and these are then held with loose flanges bolted together behind the rings, or the pipes are flanged, E.

Socketed Joints.—These allow of some play for adjustment of pipe lengths. The socket or recessed portion at one end of one pipe receives the *spigot*, or entering end of another pipe, Fig. 64, D, E, F, G. The fit is often loose, and free, but for some good work the sockets are bored and the spigots turned, E. The joint is completed by stemming or caulking with spun yarn, or a gasket, behind the spigot, held by pouring molten lead in, followed by caulking with a blunt-ended tool. Steel pipes have steel sockets riveted to them, or formed by pressure, Fig. 66, A, or thimbles, B. *See also* **Stop Ends, Thimbles, Unions**.

Flexible Joints.—The foregoing are rigid joints. There is a section of pipe work in which it is necessary to allow flexibility be-

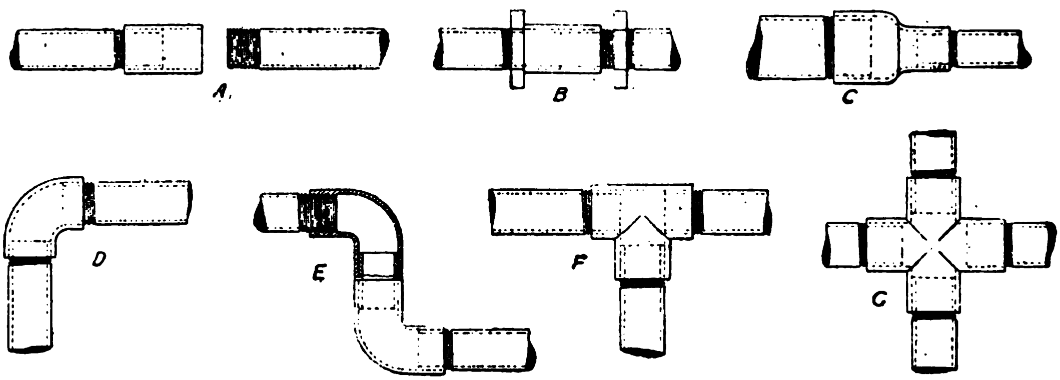


Fig. 68.—Joints in Wrought-Iron Tubes.
A. Union for Straight Tubes. *B.* Lock Nut Union. *C.* Diminishing Socket. *D, E.* Bends. *F.* Tee. *G.* Cross.

Cast iron is distrusted for pipes subjected to high steam pressures, and for hydraulic service. Steel is used in preference, and the flanges are united to the pipe, Fig. 66, C, D. Sometimes the flanges are cast, but in some cases flanges of pressed steel are employed, C, D.

tween the pipes, as when laid on irregular ground, the beds of rivers, &c. The commonest is made on the ball and socket principle, of which there are various designs, Fig. 64, F, and Fig. 67.

Screwed Joints.—These are used for wrought-iron tubes, Fig. 68, and are made in standard dimensions and to standard gas threads.

Pipe Lines.—These fill a large place in the hydraulic engineering of waterworks, turbine installations, and in alluvial mining. The pipes have to convey water for service mains, or power water under various heads, and often over long distances. Cast pipes, and pipes of steel sheet and wood are used. The pressures are often high, which makes the strength of the joints a matter of great importance. Pipe lines have to follow the contours of uneven ground, which adds to the difficulties.

Eytelwein's formula for the delivery of water in pipes is:—

$$W = 4{\cdot}71\sqrt{\frac{D^5H}{L}}$$

$$D = 0{\cdot}538\sqrt[5]{\frac{LW^2}{H}};$$

where

W = cubic feet of water discharged per minute,
D = diameter of pipe in inches,
H = head of water in feet,
L = length of pipe in feet.

Kütter's formula for the flow of water in *smooth* pipes is:—

Pipes	$\frac{1}{2}$ in. to	$2\frac{1}{2}$ in. diameter	=	$V = 107\,D^{0{\cdot}9}\sqrt{S}$
„	$2\frac{1}{2}$ „	5 „	„	$= V = 115\,D^{0{\cdot}8}\sqrt{S}$
„	5 „	10 „	„	$= V = 134\,D^{0{\cdot}7}\sqrt{S}$
„	10 „	72 „	„	$= V = 166\,D^{0{\cdot}6}\sqrt{S}$
„	6 ft. to 400 ft.		„	$= V = 256\sqrt{DS}$;

where V = velocity in feet per second,
„ D = diameter of pipe in inches,
„ S = hydraulic inclination.

The loss of head due to friction in long pipes is calculated by the following formula by Thomas Box:—

$$G = \left(\frac{(3d)^5 \times H}{L}\right)^{\frac{1}{2}}$$

$$H = \frac{G^2 \times L}{(3d)^5}$$

$$d = \left(\frac{G^2 \times L}{H}\right)^{\frac{1}{5}} \div 3$$

$$L = \frac{(3d)^5 \times H}{G^2};$$

where d = diameter of pipe in inches,
L = length in yards,
H = head of water in feet,
G = gallons per minute.

Cox's Weisbach formula is:—

$$H = \frac{l4v^2 \times 5v - 2}{d\,1200};$$

where H = total loss by friction in feet,
d = the diameter of the pipe in feet,
l = length of the pipe line in feet,
v = velocity of water in feet per second.

Bends and elbows increase friction, hence the larger the radius of bends the better. Corrosion increases the frictional resistance, which renders Angus Smith's composition so valuable.

Inclination of Pipes.—When pipes have to be laid on slopes with uneven contour, the ***hydraulic mean gradient*** is the equivalent of vertical head. That is, a sloping line drawn through the average heights corresponding with the various heights at which the water would find its level gives this gradient. The vertical height between extremes of slope is the equivalent of the head. The contour of the pipe should not be allowed to rise anywhere above the line of the hydraulic mean gradient. If this is unavoidable, then air will accumulate at the highest peaks, and will partly fill the lower pipe, causing loss of head. In some cases a safety valve has to be fitted to a pipe line. In cases where pipes are exposed to considerable changes of temperature, expansion joints are fitted at intervals.

Some of the pipe lines on the Pacific coast are of great length and head. The Standard Oil Company's pipe line extends from the Bakersfeld and Coaluya oil fields to Point Richmond in the Bay of San Francisco, a distance of 278 miles. The pipes are 8 in. bore, of open-hearth steel, subjected to a pressure of about 600 lb. per square inch. The Keswick pipe line of the Northern California Power Company is 6,800 ft. long with a maximum head of 1,204 ft. The Colgate plant of the California Gas and Electric Corporation has five lines of 30-in. pipe, each of which is 1,625 ft. long, the maximum head being 702 ft. The San Joaquin Electric Company's pipe line near Fresno has a length of 4,020 ft., and total head of 1,406 ft. There are 960 ft. of 24-in. riveted steel pipes of No. 12 gauge, 860 ft. of 24-in. riveted steel pipe of $\frac{1}{4}$ in. thickness, 400 ft. of 20-in. lap-welded $\frac{5}{16}$-in. steel; 800 ft. of

20-in. lap-welded $\frac{5}{16}$-in. steel, and 1,000 ft. of 20-in. lap-welded $\frac{3}{8}$-in. steel pipes. *See also* **Aqueduct**.

Pipe Moulding.—This is an extensive section of work, comprising not only straight, and bend pipes, flanged and socketed, but also the tees, reducing pipes, thimbles, stops, &c., in a very wide range of dimensions, and comprising the jobbing work for odd jobs, and the regular manufacture of stock sizes. Standard or stock sizes of patterns are kept in most cases, and are altered for jobbing sizes. Straight pipes, and bends with flanges, sockets, and other adjuncts, are kept, ranging say from 2 in. bore up to about 12 in. Except in the 2-in. size, the straight patterns are of standard 9 ft. lengths, and grooves are turned at the ends for the reception of flanges. Such patterns are made of wood, jointed; or if of metal, unjointed, in which case they are let into joint boards to the middle plane. For lengths less than standard a *body flange* is fitted. For lengths longer than standard, which are sometimes wanted, a special pattern is kept, or the standard one is lengthened by means of a dovetail, or by fitting the extra length over one of the prints. The standard pattern may be used for sockets and spigots. The sockets, of wood or metal, are screwed on the pipe body, and the spigots are formed of strips of lead bent round and nailed. Branches are fitted when required at right or other angles by means of butt joints and screws.

Bends.—Standard pattern bends are kept in stock, with flanges, sockets, and spigots, each being distinct patterns. They are seldom altered, but odd bends are kept for such work for flanged, and socketed fittings, and for attachment to straight lengths of pipe when bends have to be cast with these. The bend lengths are attached to each other, and to pipes with dovetails.

Tees.—These are kept in standard, and in jobbing sizes both for flanged, and socketed, and spigoted ends. The jobbing patterns are altered in respect of length, position, and size of tees for making odd connections.

Moulds.—The jobbing pipes are moulded by the ordinary methods of the foundry, and in common boxes. They are generally made by turning over. Box sides for straight pipes are often bevelled from the joint faces to lessen the sand space, and the amount of ramming required. Bends are moulded in boxes formed at suitable angles, and having bars to suit. Tees have boxes with branches. But when work of exceptional length, and having branches at sides or top or bottom is required, any boxes are selected which happen to suit, and makeshift methods are adopted.

Cores.—The cores for pipe work are made according to circumstances, by all the methods of the core maker. They are rammed in boxes if the number off is sufficient to pay for the boxes. Bends and tees are usually made thus. But cores for straight pipes are often, even though small, swept up in loam on a bar, and all large pipe cores are so made. The bars are wound with hay bands, and the cores are dried. Branch cores are butt-jointed to the main cores in the mould, and often also bend cores to straight lengths.

Loam Work.—This is reserved for massive castings, and for unusual sizes and shapes. Straight pipes, and bends are both made in this way. The pipes are swept against a board, and flanges or sockets fitted to the loam. Bends are swept with strickles against a guide iron. *See* **Bend Pipes.** Sometimes the core is struck first, and the pattern thickness added, but if numbers are required off, the pattern is distinct from the cores. Loam work is of high value in this class of work. Though expensive, it is not so much so as pattern construction in timber would be. There is no shape so difficult that it cannot be produced by strickles, guide irons, and thickness pieces.

Methods of Casting.—Pipes are cast horizontally in the jobbing shops. The objection to this is the floating of scum to the top, where it is liable to lodge, and cause sponginess, and blow holes. This may be largely avoided by using risers, and by having hot clean metal of suitable grade. Another objection is the tendency of the core to rise about the centre, making the metal thinner in the top than in the bottom. The risk of this may be avoided by careful chapleting. But the free use of chaplets is undesirable in pipes which have to stand much pressure, because leakage often occurs around

the chaplets. Hence in the regular pipe foundries the pipes are cast on a bank having a slope of from 30° to 45° from the horizontal; or they are poured vertically. The first named is still open to the same objection as horizontal casting, the second is not; the latter is therefore very general for small as well as large pipes which have to be subjected to severe pressures. The cores are retained centrally, without chaplets, and the metal is of equal soundness throughout.

Pipes Moulded Vertically.—Figs. 69 and 70 illustrate one method of casting pipes vertically. The socketed end is laid face downwards, fitting within a ramming ring, and a portion of the moulding box corresponding with the socket is laid on the ring, to which it is dowelled, and rammed up to the joint face. The main body of the moulding box is then put over and rammed to the bottom of the bead ring. This ring is formed in loose segments round the body of the pattern. This is rammed, and then the print ring above, the box parts being clamped to each other. The main body of the pattern is then withdrawn, followed by the lifting of the main box. The socket pattern is next withdrawn, and the bead segments and print rin[illegible] [illegible]ing [illegible] moved and [illegible] vered [illegible]; fits into the bottom plate. This portion is rammed in a core box. The barrel of the body core fits into the socket ring by a register of angular section. At the top, the body core is encircled by a covering core. It is centred with a gauge, and then wedged centrally by wedges between the main and the covering cores.

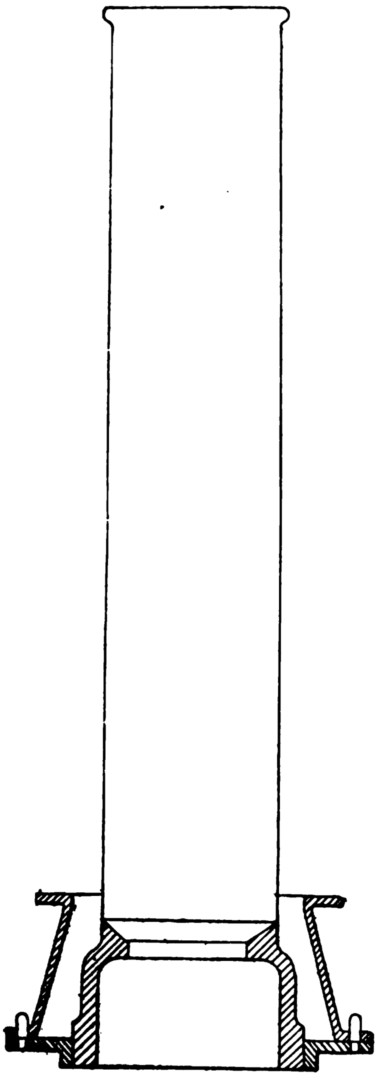


Fig. 69.—
First Stage in Pipe Moulding.

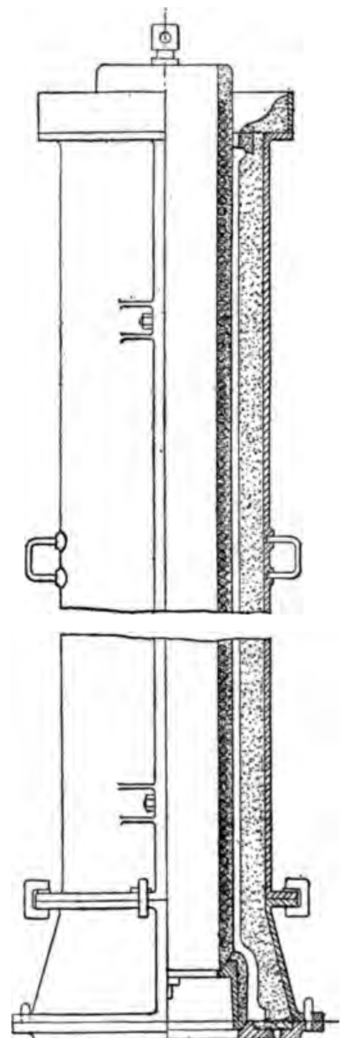


Fig. 70.—
Pipe Mould Completed.

Figs. 71 and 72 illustrate the moulding of the smaller pipes vertically as practised in the foundry of Messrs R. D. Wood & Co., of Philadelphia. Both drawings show socketed

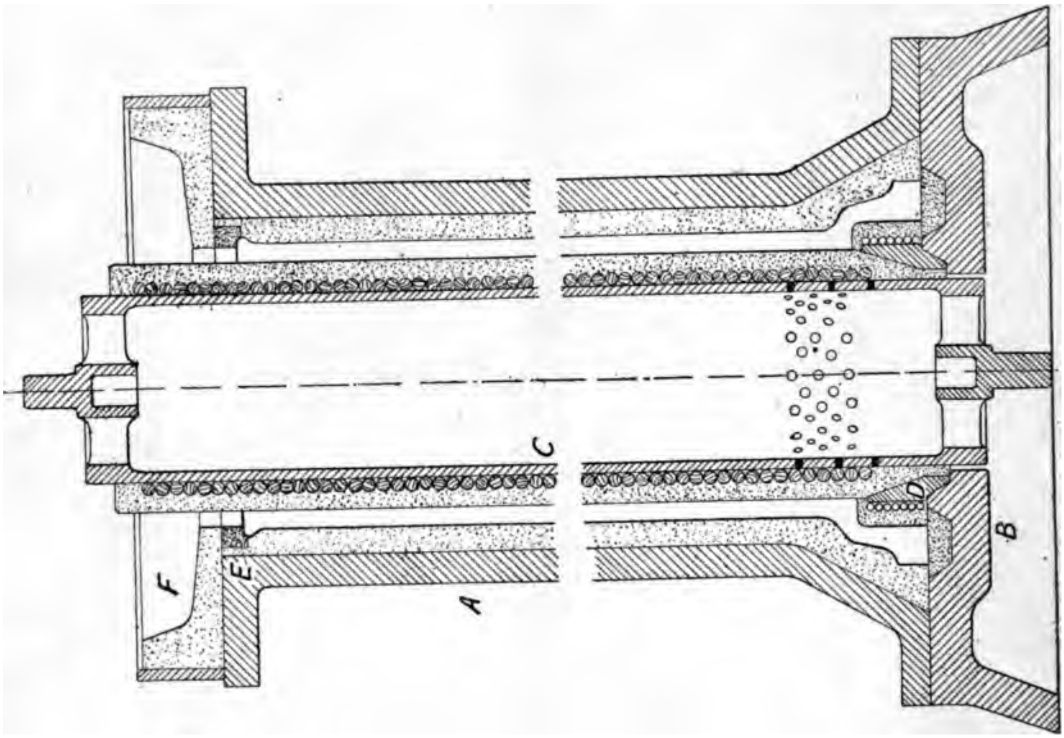


Fig. 72.—Pipe Moulded with Socket Lowermost.

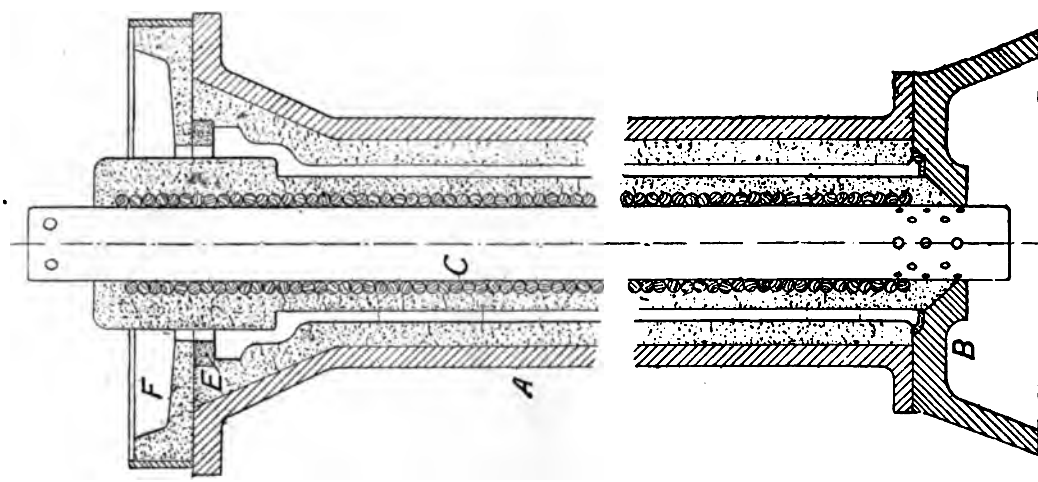


Fig. 71.—Pipe Moulded with Socket Uppermost.

pipes, but the socket is in the top in one case, in the bottom alternatively in the other. The parts lettered are as follows: A is the moulding box body, made in one for the small pipes, but in two or three parts for the larger. B, the base which carries the mould, is chilled. C is the core bar; D, the core ring on which the socket portion of the mould is rammed, and having a tapered bore by which the body core is centred; E the bead ring which receives one-half the bead mould, forming the parting joint. In Fig. 71, where the socket is uppermost, the ring serves for centring the core only. The core is swept up on straw ropes shown, the mould rammed round the pattern, and lifted away. Core and mould are dried in the stove, and returned to place, the mould closed, the pouring basin, F, prepared and put on, the pouring being done in a pit.

Thicknesses.—The thicknesses of cast pipes are much in excess of those deduced by calculations. This is necessary, because of the uncertainties attendant on casting, and on the porous nature of cast iron, and its liability to crack under sudden shock. Pipes are generally specified to be of a certain weight as well as thickness, to guard against thinning or thickening of the core away from the ends.

The Weight of Pipes.—This is readily calculated by multiplying the contents in cubic inches by 0·263 for cast iron. The cubic inches can be obtained by deducting the inner from the outer diameter, and multiplying the section obtained by a given length of pipe, say a foot, or a yard. Generally the weight of two flanges is taken as equal to that of 12 inches length of pipe.

Pipe Nails.—*See* **Chaplets.**

Pipe Scraper.—Designed for removing the incrustation which forms on the interior of water mains. It is actuated by pressure due to the head of water in the pipes. It comprises knives, kept in position by steel springs, which act with a definite pressure on the interior of the pipe, but which yield to an excess of pressure. Thus, in one example, the working pressure being 48 lb., the yielding point was 60 lb. The pressure of the water is taken against pistons in the rear of the knives, and fitted with leather washers. The two portions are connected with a swivel joint, which permits the scraper to pass through bends of large radius. A gain in delivery of from 30 to 50 per cent. has often been obtained by scraping pipes.

Pipe Stoves.—*See* **Hot Blast Stoves.**

Pipe Templets.—It is usual to fit make-up lengths of pipe for the completion of connections, by the help of templets rather than by

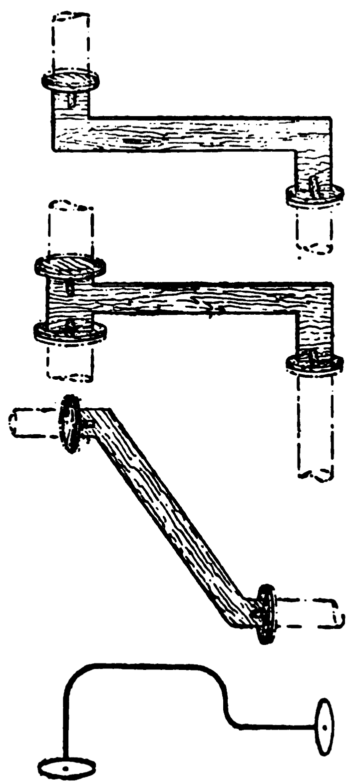


Fig. 73.—Pipe Templets.

measurement. More exact fitting is ensured, with less risk of error. It is difficult to take measurements when flanges are not square, or when bends have to pass round parts of machinery, or when pipes of special forms have to be made. Generally for cast pipes, wooden templets are fitted by the pattern-maker or carpenter; for drawn pipes, iron rod is bent, and flanges when required are represented by templet flanges of sheet iron riveted on the ends. It does not matter how rough the body of a templet is if the fitting parts are accurate. The end flanges are the only essentials, which must correspond with the flanges to which the

connecting pipe has to be bolted. The body is generally a bit of plain board, and the flanges are nailed to the ends and retained accurately with brackets. Often, however, the body is made to indicate all that the pattern-maker and moulder wants to know. The width corresponds with that of the outside diameter of the pipe, and the bore is marked on, and the thickness of metal shaded. The position of the bolt holes may be marked on the flanges. A few typical templets are shown in Fig. 73.

Pipe Threads.—*See* **Screw Threads.**

Piping.—The formation of a shrinkage caving in the upper portions of steel ingots. The head in which it occurs has to be sawn off. *See* **Ingot.**

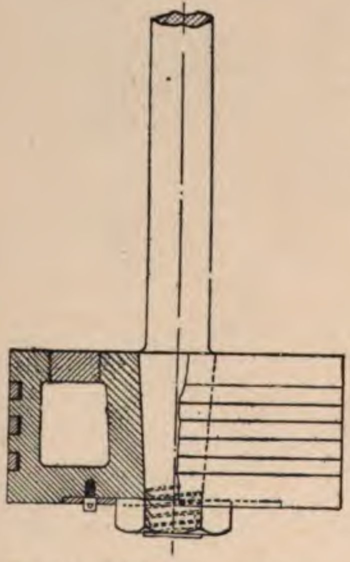


Fig. 74.—Solid Piston, with Ramsbottom Spring Rings.

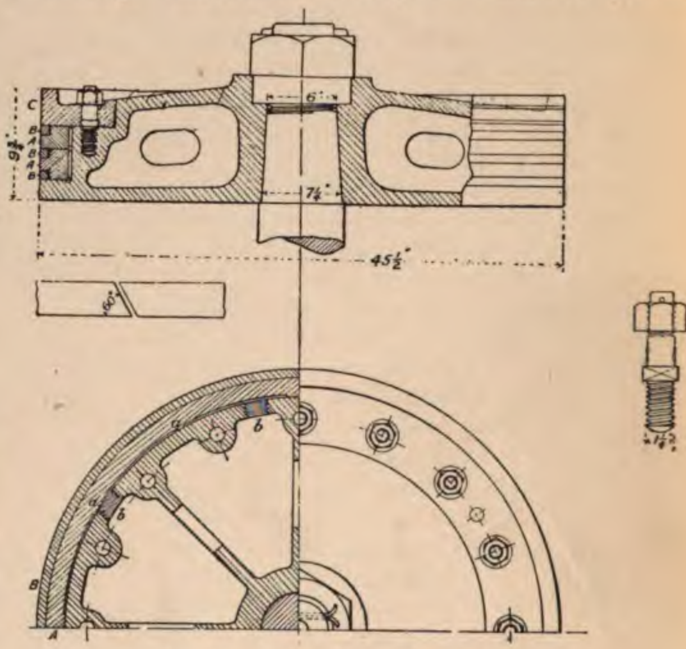


Fig. 75.—Piston of Marine Engine.

Piston.—A body which is caused to slide in an enclosed vessel by fluid pressure or against fluid pressure. It may drive, or be driven, by a crank. A bucket or plunger is the piston of a pump, a ram is an hydraulic piston. The term is therefore restricted commonly to the piston of a steam, or an internal combustion engine.

The simplest pistons are plain discs. But as these are not perfectly steam-tight, they are not used in commercial engines, but packings of various kinds are employed. With increase in steam pressures and temperatures the older packings have given trouble, and new types have been introduced and are now very numerous. The dimensions of pistons modify the designs, so that there is scarcely anything in common between one of 6 in. and of 6 ft. in diameter.

The simplest piston comprises two plates—the piston body, and the top plate, enclosing the metallic packing ring. Many of these are made, and used for small engines. Another comprises a solid body fitted with Ramsbottom spring rings, expanded and sprung into grooves turned in the body, Fig. 74. The plates are sometimes coned, as are those of the largest pistons, in order to give more strength to resist pressures than flat discs would do.

Piston rings are turned a little larger than the bore of the cylinder, at the rate of about one-eighth of an inch per foot of diameter, then cut through at an angle of 60°, and sprung inwards, so giving the elasticity required. They may be single, or two or more rings may be fitted as is usual in all but the smallest pistons.

Large pistons are ribbed, and cast hollow in the larger sizes, Fig. 75. The strains on a

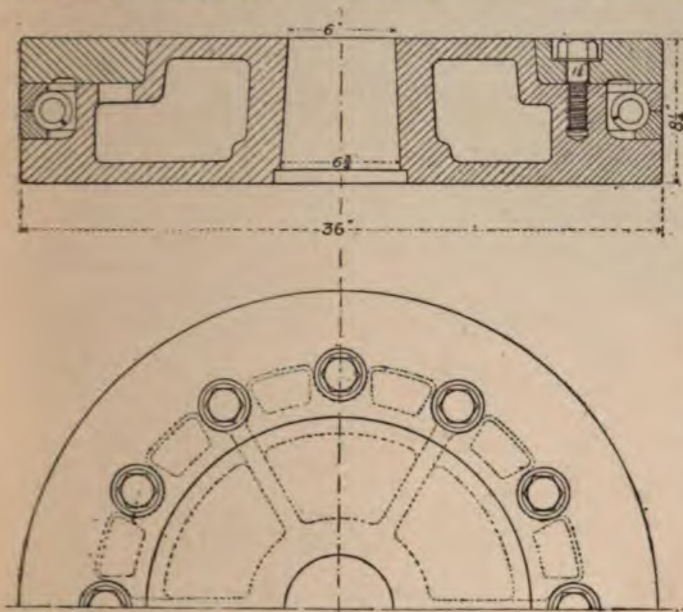


Fig. 76.—Piston of Marine Engine.

piston of large area are enormous, and great care has to be exercised in the designing of these, and the practice is largely empirical. The shrinkage strains of castings have to be nicely balanced, otherwise large pistons are liable to fracture. The weight of marine pistons is so great that lifting eyes have to be screwed into them, as into the cylinder covers, to permit of their being lifted out by the overhead travelling crane.

Fig. 75 illustrates the piston of an intermediate engine, by Wm. Doxford & Sons, Ltd., in which packing rings A, fitting by guides at *a* to the piston body, have Ramsbottom rings B, the whole confined by a junk ring C. The holes *b* in the piston body are for removing the core through, being afterwards filled with screwed plugs. Fig. 76 is a high-pressure piston by the same firm, in which the rings are pressed outwards by a coiled spring.

Cast iron is used for pistons of small dimensions. Cast steel divides favour for those of large size, because it combines strength with lightness. In many of the modern marine engines, the pistons of the high-pressure cylinders are of forged steel, so gaining a further advantage. The risks and delays which may follow from the fracture of a piston at sea are too serious to be taken.

The Lancaster piston rings enclose a steel spiral spring, Fig. 77, which is gauged to exercise a definite pressure on the rings. The same idea, but with the action reversed, is embodied in the firm's metallic packing (*see* Vol. VI., p. 184, Fig. 206). Provision is made for altering the tension of the spring when necessary by screwing the ends of the rings into one another. By varying the distance to which one end screws into the other, the diameter of the spring can be altered to put more or less pressure on the rings. Compensation is thus afforded for wear, or for increase in pressure. The action of the spring operates both radially, and in the plane of the piston block and junk ring, so making the piston

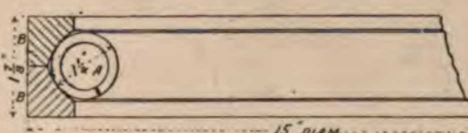


Fig. 77.—Lancaster Piston Ring. (Lancaster & Tonge, Ltd.)

steam-tight in both directions, with a minimum of friction.

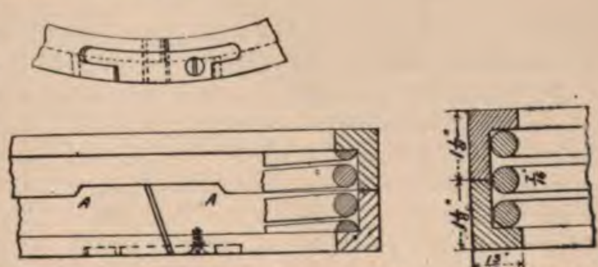


Fig. 78.—Lancaster Serpent Coil.

Another of the Lancaster patents is the *serpent coil*, Fig. 78. It is a coiled spring of

round steel, enclosed between the rings and the piston body. It is suitable for use in pistons where the flat coiled springs have been fitted, being free from the liability to bind fast, which is an evil in flat springs. It is used largely in traction engines.

Piston Rods.—These are of steel, fitting generally to the piston with a coned end, tapering about 1 inch per foot, and a nut. Sometimes the fitting is parallel for the greater portion of the length, with a steep coning at the entrance. The stress on the rod is equal to the maximum stress on the piston.

Piston Ring Grinders.—Piston rods are commonly ground in the ordinary cylindrical grinding machines, or in special machines of similar but simpler design. The faces of piston rings are now often ground on machines which in general build resemble the vertical boring machines. One of these by J. E. Reinecker is shown by Fig. 79. In this illustration A is the main framing, B the work table which is rotated from the belt C on the pulleys D, E, through bevel gears F, and spur gears G, and H. The variable drive of the table to suit work of different diameters is derived from the reversed cones J and K, driving to the cone D. The belt is operated by a rack (not shown).

The cross traverse of the grinding wheel is derived from the stepped cones L, on the same shaft as E, driving to M above on the shaft N, thence through bevel gears to the vertical shaft P, actuating gears Q, comprising bevels, worm, and worm wheel; by which the worm and worm wheel drive in opposite directions, reversing the motion of the traverse feed screw R, and thence the wheel head S. The striking dogs are seen at *a*, *a*, and the dogs at *b*, *b* actuate the reversing lever *c*. T is the handwheel for the head.

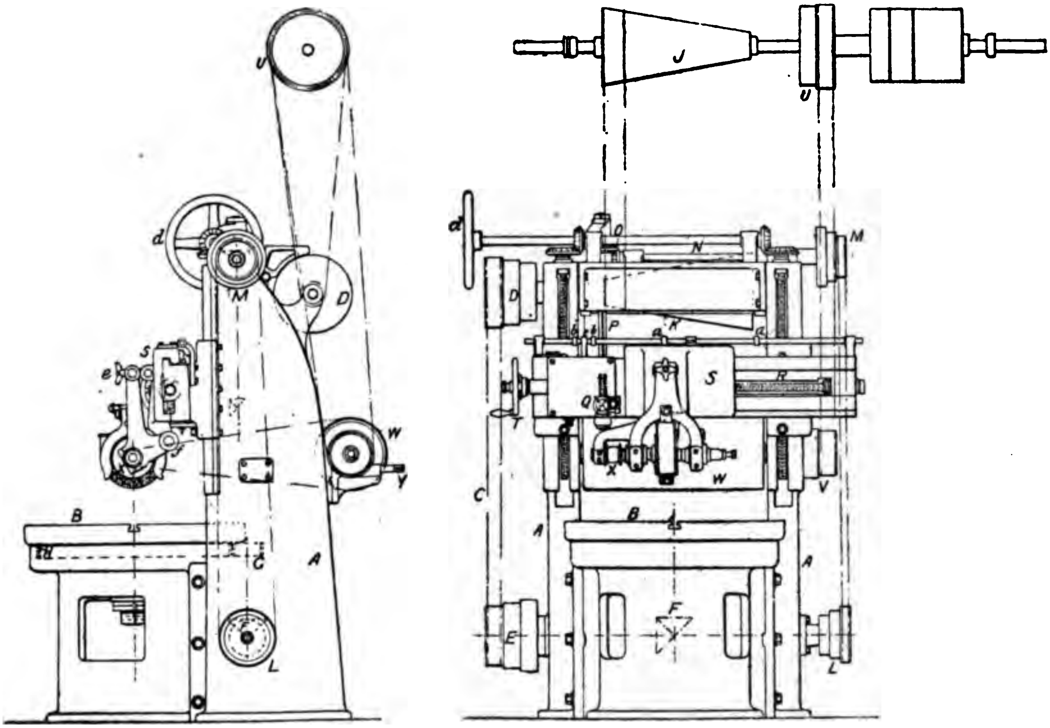


Fig. 79.—Piston Ring Grinder.

The grinding wheel is revolved from the stepped pulleys U on the countershaft, driving to the cones V on the shaft of the drum W. The latter is belted to the pulley X on the grinding spindle. The tension of the short belt is adjusted by the screw Y, by which

the bearings of the drum are moved along horizontally. The cross-rail is adjusted vertically by bevel gears and screws from the hand-wheel *d*. The screw *e* gives the fine vertical feed of the wheel, the bearings being hinged at *f*.

Piston Speed.—The rate of travel of a piston in feet per minute. It is one of the elements in the smooth running of an engine, and the longer the stroke, the better can cut-off and cushioning be regulated. The piston movement varies from rest at each end of the stroke to maximum at nearly mid-stroke, the varying rates of which can be deduced from the uniform rotation of the crankpin.

Piston speeds were formerly taken at 220 ft. per minute. They now run to 600 ft. in short-stroke high-speed engines, to 800 ft. in marine engines, and 1,000 to 1,200 ft. in locomotives. High piston speeds are economical, because power is exerted in proportion to speed. Thus a speed of 800 ft. will give twice the power of one of 400 ft. with equal pressure. High pressures and speeds are therefore economical, but the limits are set by the effects of inertia and momentum on the moving parts themselves, and on the crankpin. Hence with increase in speeds, the mechanical difficulties of construction have increased, and had to be surmounted. An important detail is concerned with the weight of moving parts, which is kept down as much as possible, and which explains the substitution of steel for iron, and the best distribution of metal to secure lightness with strength. Another is the equal distribution of rotational effort by dividing the stress between the cranks at angles of 120° apart in triple expansion engines, and by judicious counterbalancing in single cylinders, and two-cylinder compounds. The distribution of steam also is of much importance, particularly the exact amount of cushioning at the termination of a stroke. The piston speed is found by multiplying twice the length of stroke in feet by the number of revolutions of the crankshaft per minute.

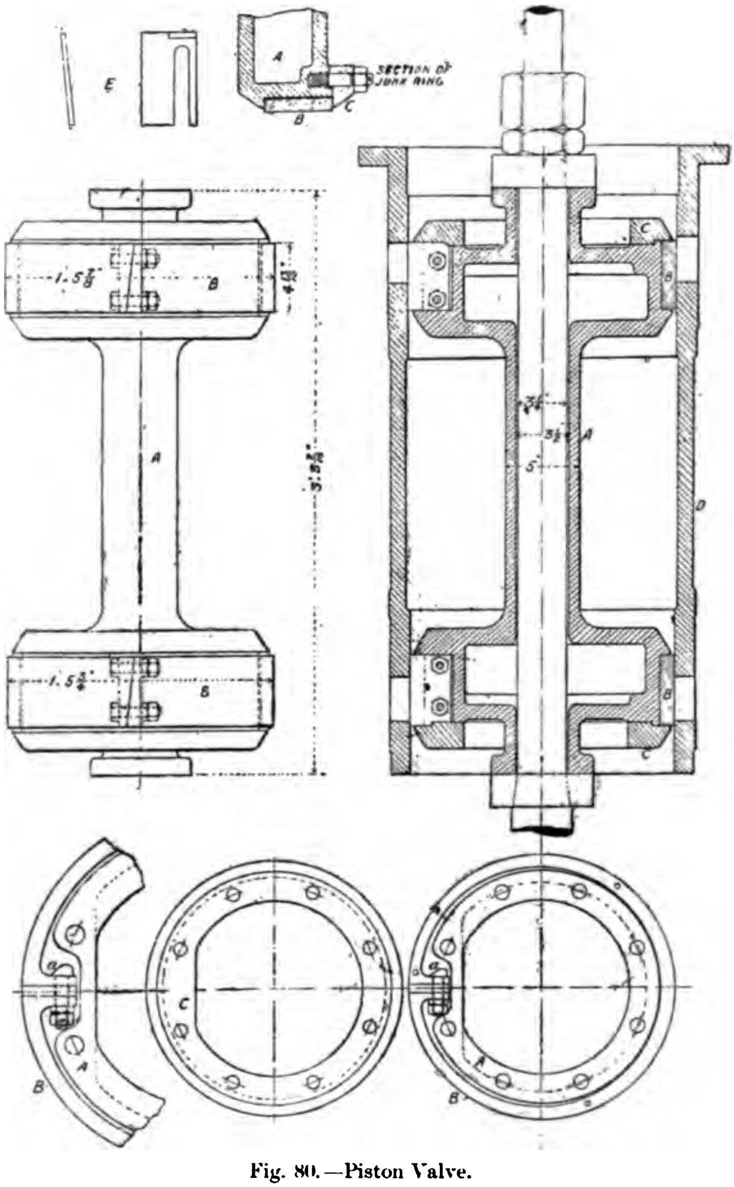


Fig. 80.—Piston Valve.

Piston Valve, or **Plug Valve**.—The best type of balanced valve. It is a block piston of circular section, fitted with spring rings, and is used both because it occupies less space for equal area of parts than the flat valves do, and also because it is in equilibrium. It is therefore used for the high-pressure cylinders of marine engines, frequently also for the intermediate, and low-pressure cylinders, and latterly it has been applied to locomotives. The valve is in two portions, connected by a stem, solid in the smaller sizes, or hollow in the larger. The steam enters on the outer faces and exhausts between. In order to avoid the spring of the rings into the ports as they pass, bridge bars are cast diagonally across the ports. Lap is allowed as in ordinary valves. Piston valves are simple, or they are provided with variable cut-off.

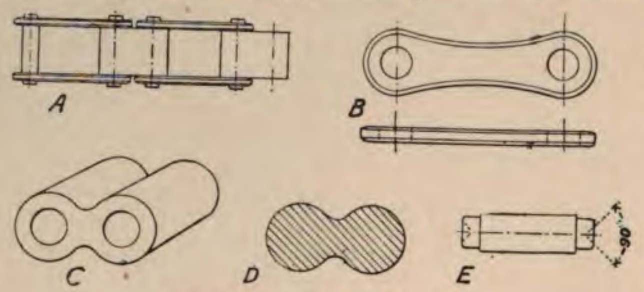


Fig. 81.—Renold Block Chain.
A. Chain. *B.* Link. *C.* Block. *D.* Block before Drilling. *E.* Stud.

Fig. 80 illustrates a large piston valve for a marine engine built by Messrs William Doxford & Sons, Ltd. The rod passes through the body A, with $\frac{1}{4}$ in. of clearance. The eccentric packing rings B are bolted with internal lugs. The heads of the bolts at *a* are cut away to permit of withdrawing them. Junk rings C hold the rings in place. The rings are turned up one-eighth larger in diameter than the liner D. Four brass liners, E, are supplied with each ring to insert in the joint to take up wear.

Pitch.—The distance from centre to centre of gear wheel teeth (*see* **Gears**); of screw threads, of pitch chains, of rivets, or bolts, or other details.

Pitch Chains.—Chains used for driving and lifting purposes, and made to exact centres between links for fitting around sprocket wheels; hence sometimes termed *gearing* chains.

Flat Link Chains, or *Stud Chains*, or *Pin and Link Chains*.—These are the type used for practically all heavy engineers' slow speed driving, especially for travelling cranes, dredgers, pile drivers, excavators, conveying apparatus. This design, in which short flat links are connected with pins, and in which the open spaces between the links fit over and around the teeth of the sprocket wheels, is varied much in regard to the shape and number of the links. Many chains have pairs of links only, in others the necessary strength is made up of two, three, or more thinner plates interlocking at the locations through which the pins pass. The pins in all cases are shouldered to maintain the links at their proper distance apart, and they are secured outside by riveting. Wrought iron or steel stampings are generally used. The edges of links are parallel, or concave, the latter shape having the effect of lightening the chain, though maintaining equal strength in the middle compared with the section through the eye.

Block Chains.—These comprise solid steel blocks, connected by steel flat side links, and united by shouldered studs, which pass through holes drilled and reamered in the blocks and links. The sides of the blocks are made concave to lessen weight. The elements of the block chains as made by Hans Renold, Ltd., are shown in Fig. 81. These chains are made in pitches up to 5 in. The working

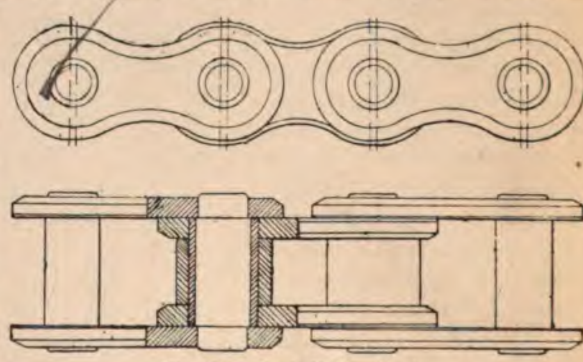


Fig. 82.—Bush Roller Chain.

loads uniformly allowed for are given at one-tenth of the breaking strength. But these may be less or more according to conditions of driving. For severe work Mr Renold says that no greater working load should be used than one-thirtieth of the breaking strength. Chains should run at an easy degree of tension. They should be lubricated with oil applied with a brush, or the chain runs in an oil bath.

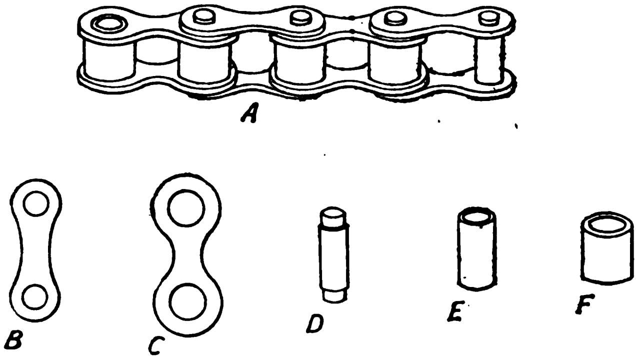


Fig. 83.—Bush Roller Chain Parts.
A. Assembled Chain. *B.* Inner Link. *C.* Outer Link. *D.* Stud. *E.* Inner Bush. *F.* Outer Roller.

Bush Roller Chain.—This, Fig. 82, is an invention of Mr Renold, designed to avoid the excessive wear on the inside link joints, the elongation of the inside links, and the grooving of the pivots of the common roller chain. In the bush chain a large bearing surface is provided for the pivot. It comprises two parts, the outside element, and the inside element (*see* Figs. 82 and 83). The outside links are riveted to shouldered pivots with large bodies. The necks of the pivots are forced by presses into the links and riveted over. The pivots are encircled by bushes which form pivots on which the friction rollers turn, and which provide the long bearing surface essential to durability. Block chains are used for the slower speeds up to about 400 ft. per minute. Roller chains will run up to 800 ft. per minute for the larger sizes.

The Silent Chain. — The Renold silent chain, Fig. 84, consists of interlocking plate links with a vee formation, united with shouldered studs and washers. There are several advantages in this design. The work is distributed over several teeth, and the wearing surface is so large that stretching is minimised. The plates which make up the chain have each two holes, with a small and a large recess cut out, as shown in the detail, Fig. 84. Segmental bushings, A, are forced into the smaller recesses, so that each

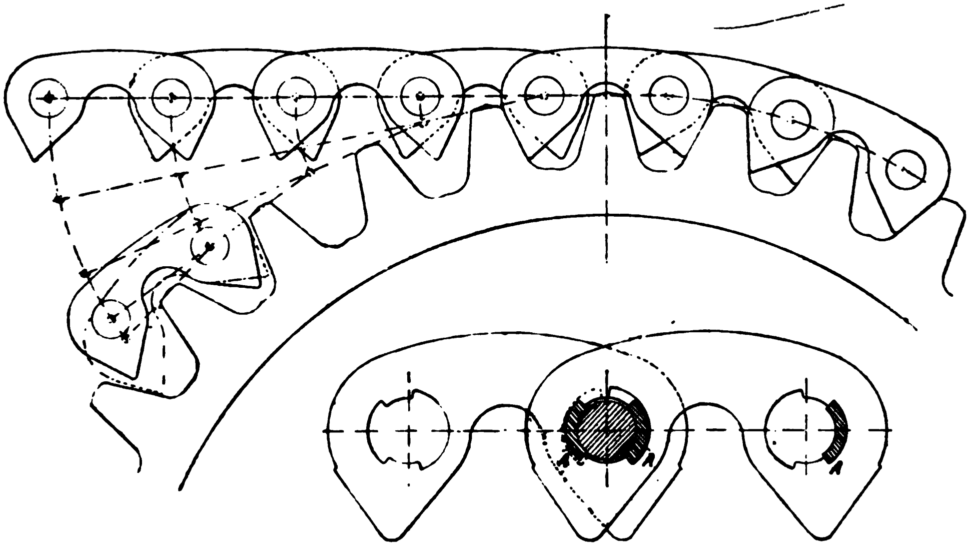


Fig. 84.—Renold Silent Chain. Appearance of chain entering or leaving wheel, with detail of joint.
A, A, A. Segmental Bushings.

link, therefore, carries two bushings, the latter projecting through the large clearance space in the adjacent link, and fitting the further one closely. The links are thus free to pivot on the central studs, which can rotate without hindrance, and so distribute the wear evenly. Both the bushings and the studs are hardened. The number of links which are strung together depends on the width of chain desired. To keep the chain from moving off its sprockets laterally, two devices are employed: in one, guide plates are mounted in the central portion between the links, these plates running in a groove cut around the sprocket. But when one of the sprockets has considerable end play, lateral freedom is allowed the chain, by putting flanges on the sprocket, to keep the chain from running off. Increase of strength and driving power can be obtained without increase of pitch, simply by widening the chain; noiselessness is secured, because the chain links glide gradually into gear with the teeth. It runs noiselessly at speeds of from 1,000 to 1,600 ft. per minute.

The Renold Wheels.—These are designed to avoid the evils inherent in those roller chain wheels in which the attempt is made to ensure fitting of the rollers with all the teeth in the working arc of the wheel. But such exact fitting is impossible in practice, because the chain stretches within a very short time after being put to work. As the wear on the wheel may be nearly left out of consideration, Mr Renold

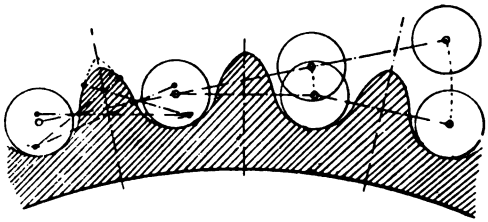


Fig. 85.—Diagram showing Tooth construction for Roller Chain.

designs his wheels so that the pitch of the driver wheel is longer than that of the chain, and the tooth space wider than that required for the reception of the roller. Fig. 85 shows the method of obtaining tooth construction, from which the locations of the various radii can be noted. The pitch of the driven wheel is made the same as that of the chain, but the tooth spaces are also wider than the rollers. The result is that the load is distributed over a number of teeth, and in both cases the incoming

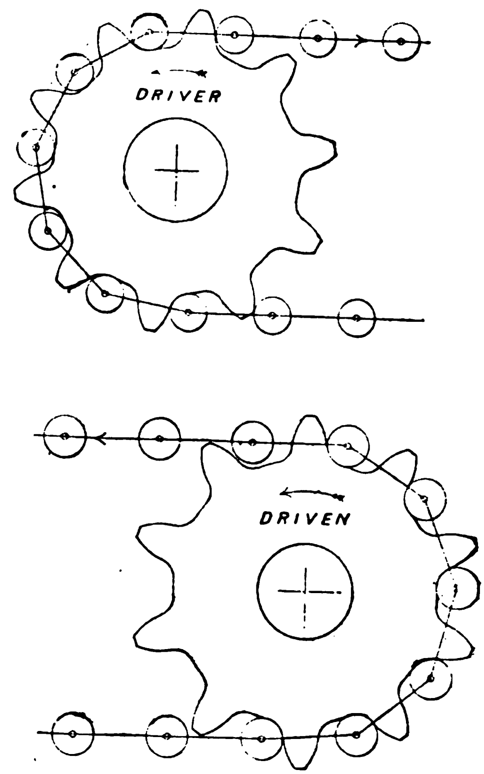


Fig. 86.—Driver and Driven Wheels.

roller makes contact with the side of the tooth which does not transmit the load. It is thus able to get properly bedded down before being called upon to take up its share of the load. Fig. 86 shows how the teeth have been made for many years, but their shape is now modified to that seen in Fig. 85. The bottom of the space is made with a larger radius than that of the roller. This still leaves some play in the tooth gap, but not so much as formerly. Every roller beds in its tooth gap, and the rolling action is more easy and continuous.

The Morse chain embodies a novel style of joint, in which sliding contact is replaced by rolling contact. The links are connected by a series of approximately triangular pins, one of

which presents a rounding face to the flat face of another, one of each kind being fixed in opposite ends of a link. As the chain moves around its wheel, one pin rolls its face against its companion, giving a very smooth action without sliding friction. The need for lubrication is much lessened, and very high speeds can be attained.

Conveyor Chains.—The ever-increasing employment of conveying systems has developed numerous designs of chain belts suited to every class of service. Many of these are fitted with attachments taking the form of special links. They carry all kinds of brackets, scrapers, and other fittings.

Pitchometer.—An instrument for measuring the pitch of a screw propeller blade by the rule of proportion, in which a fraction of the pitch measured is to the whole pitch as a fraction of circumference measured is to the whole circumference. It is a stiff wooden framing fitting on the shaft, and extending to the circumference. Two sides of the framing form a definite angle, say 15°, and a middle bar $7\frac{1}{2}$°. Measurement is taken from the edges of these bars to the face of the blade. The fractional pitch will therefore be $\frac{360}{15} = \frac{1}{24}$; or $\frac{360}{7\frac{1}{2}} = \frac{1}{48}$ of the circumference. Hence from the measurements taken, the pitch which corresponds with the distance between blades in one revolution can be deduced.

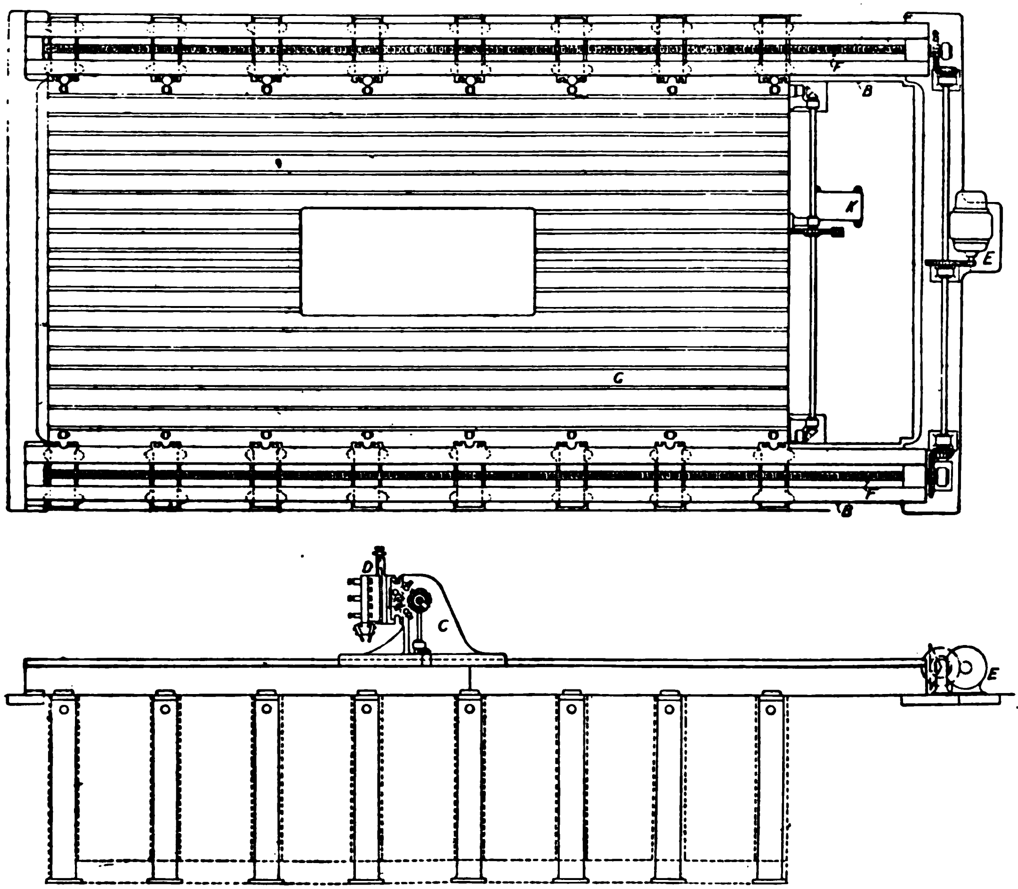


Fig. 87.—Pit Planing Machine. (Plan and Side Elevation.)

Pitch Pine (*Pinus palustris, Pinus australis, Pinus rigida.* Natural order Coniferæ).—A tree growing in the Southern parts of the United States, and valuable for engineers'

timber structures, because of its large dimensions, strength, resinous property, and straight grain. A cubic foot weighs from 37 to 44 lb. It is more durable than yellow pine in situations where it is subject to alternate wetness and dryness, but it rots quickly in a warm moist atmosphere. It does not take paint.

Pit Planing Machines.—A class used principally for planing armour plates, and other pieces of great weight. The problem of moving a heavy table with a massive plate upon it is got over by fixing the work in a pit, between two slide-ways, along which the uprights and cross-rail carrying the tool-boxes travel. The floor area required by the machine is greatly lessened, because there is no clearance wanted for the passage of a table at each end.

Figs. 87 and 88 show a machine by Messrs Sir W. G. Armstrong, Whitworth, & Co., Ltd., which has two tool-boxes on the rail, each carrying two tools. The travel and quick return of the rail and its uprights are effected by large screws lying within each slide-way.

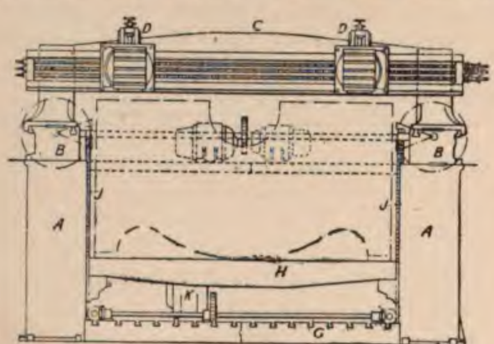


Fig. 88.—Pit Planing Machine. (End Elevation.)

In these figures, A A are the uprights carrying the slide-ways B B, C is the cross-slide carrying the tool-boxes D D, E is the motor driving the screws F F for the travel of the cross-rail, G is the bed to which deep work is bolted. H represents a series of cross-bars adjustable in regard to height, operated by screws J J from the motor K through spur, bevel, and worm gears. A turbine casing is seen outlined in Fig. 88, being the work for which the machine was specially designed.

Pits.—These have to be provided in some shops, as foundries, machine shops, erecting shops. In the foundries they are used for casting deep work, in machine shops in front of some large face lathes, shaping and drilling machines, to receive pieces of work of too large diameter, or too deep, or too long to be carried between the machine and the floor level. In the erecting shop they are used for building over, or for carrying out tests, or both. They are lined with bricks and covered temporarily with loose boards, or chequered plates when not in use.

Pitting.—That form of internal corrosion in steam boilers in which holes, or patches of holes occur on the plates. It is due to chemical action caused by using unsuitable water.

Pivot, Pivot Bearing.—A bearing which sustains the end vertical thrust of a turntable, a swing bridge, a boring machine table, and similar structures. A pivot may be long and slender, or short and rigid. A convex surface is preferred to a flat one. Turntables and swing bridges have generally a convex bearing, which terminates the massive casting that takes the load. The sagging or rocking which would result from this form is taken on a ring of live rollers. In a boring mill the weight of the table is carried on a pivot only for light work, but on an annular face in addition for heavy turning and boring. *See* **Boring Mill, Schiele's Curve.**

Plain Milling Machine.—A machine which is not provided with a swivel table, spiral head, and change gears for cutting spiral gears, and spiral cutters. Nearly all machines are of this type, almost the only exception being the Universal machine, of pillar and knee type. With the exception of the addition just named, the Universal and plain machines are built on nearly identical models, described under **Universal Milling Machines.**

Plane.—Wood-workers' planes are made in various forms and sizes, but the principle in all is to secure the cutter in a body which limits the shaving to a given thickness, and acts as a guide in levelling inequalities on the surface of the wood. There are three planes constantly used for ordinary surface work; the *Jack*, *Trying*, and *Smoothing* planes. Collectively they are sometimes called bench planes because

they are always kept on the bench, while others used for special purposes are not so constantly wanted, and may be kept in a tool chest or drawer. A thin strip of wood is put on the bench near the front end, and the fore parts of the bench planes rest on this, so preventing injury to their cutting edges by contact with the bench. Fig. 89 is a section through the mouth of an ordinary double-ironed plane, which may be either of the three kinds just mentioned, for except for slight differences in width, and way of grinding the irons, the mouths and irons are all alike. A back, or "top" iron B is screwed on the face of the cutting iron A to

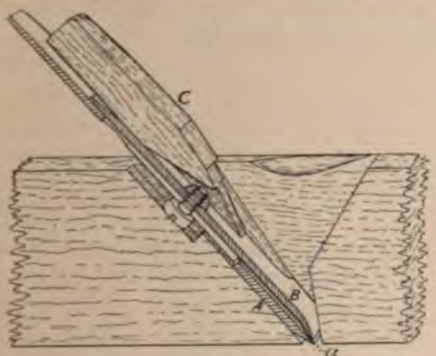


Fig. 89.—Section through Mouth of Plane.

stiffen it, to minimise tearing up of cross grain, and to enable it to cut a finer shaving. In jack planes kept for coarse work the back iron is sometimes not used. In all planes except the jack, trying, and smoothing, single irons only are the rule. The irons lie at an angle of about 50° with the sole of the plane, and are put in with the ground angle at the back. C is the wedge. In some small iron planes with cutters at very low angles the reverse position is adopted.

The first plane used on a piece of wood that is rough, untrue, or requires a considerable amount taken off, is the jack. To enable it to cut thick shavings, its iron is ground with a considerable amount of curvature, so that a shaving the full width of the iron may be nearly $\frac{1}{16}$ in. thick in the middle, tapering to nothing at the edges. This, of course, leaves perceptible waves or ridges on the surface planed, and these are removed by the trying or smoothing planes, whose irons are almost straight, being rounded slightly up at the corners to prevent their digging in and leaving ridges. For producing true surfaces of considerable area the trying plane is always used after the jack. Its iron is wider and its body longer. For planing long joints a plane longer than the trying is sometimes used, known as a *Jointer*. The smoothing plane is very short, and is not intended for making surfaces true, but only for cleaning and smoothing them. It is not used at all where truth is important. The jack and trying planes are provided with handles, but the body of the smoothing plane is grasped in the hands. Jack, trying, and smoothing planes are made either with wood or metal bodies. The latter are better, but their extra cost has prevented them from coming into such common use as the wood ones. The soles of wood planes wear and require truing up occasionally. They are hardened by applications of linseed oil.

With the exception of small metal planes, of which there are a considerable variety, none of the other kinds of plane are used for flat surfaces, but for special purposes, such as grooving, rebating, moulding. The *Plough* is a plane often required for ploughing grooves for panels, or for tongues in edge joints. It has a set of irons of different widths, and these can be set to cut to a given depth and distance from the edge which the plane works against. The *Fillister* is a slightly different plane of similar character. The *Rebate* plane has an iron the full width of its sole, which is consequently cut completely through at each side instead of enclosing the iron as in the jack and other planes. This enables it to plane out a rebate, or work against and cut right up to a shoulder. Narrow planes with rounding soles are often required for planing hollows, and there is a great variety of planes for mouldings. These have their soles and irons of a cross section to suit definite contours. Simple hollows can be planed if necessary by a plane of considerably quicker sweep, but a plane for a compound moulding can only be used for a moulding of that size and contour. Mouldings can also be planed in detail by using separate rebates, and hollow and round-soled planes, and marking lines to plane by. As a rule, however, such work is not done by hand at all.

Planer Centres.—*See* **Machine Centres.**

Planet Gear.—When a wheel rotates, gearing with another wheel, and its axis at the same time describes a circular path the centre of which coincides with the centre of the other wheel, the term planet motion, or sun and planet motion, is applied. It was adopted by Watt to convert the reciprocating motion of his early beam engines into circular motion. It was the patenting by Pickard, in 1780, of the application of the crank and connecting rod to the turning of the flywheel that forestalled Watt, and compelled him to adopt the various planet mechanisms until the patent of Pickard expired.

In Watt's patent, 1781, a toothed wheel fixed on the flywheel shaft was rotated by a planet wheel fixed on the end of the connecting rod. A pin at the back of the latter wheel was coerced by a groove in a wheel which maintained the toothed gears in engagement, and so turned the flywheel shaft. If the wheels have equal numbers of teeth then the planet wheel makes two revolutions for each stroke of the engine. For examples of other planet gears, *see* **Hole Grinding Machines,** and **Link Grinding Machines.**

Planimeter.—An instrument invented by Jacob Amsler, a Swiss, by which areas of irregular outlines are read off by the instrument itself without calculation. There are several modified forms, fixed, and proportional, the difference being that the first is designed to read to one scale only, while in the second the unit of measurement can be changed to read in square inches, square centimetres, or decimetres, and in scales of so many square units to one square inch. The planimeter consists essentially of three elements, comprising two bars or arms, and a roller. One arm has a pin or pivot by which the arm is anchored. This arm is jointed at the other end to the body of the second arm, at the farther end of which is a tracer point which is used to trace over the figure to be measured. In moving over the boundary of the figure, it makes first an "upstroke" then a "downstroke," following the outline clockwise, and returning to the point from which it started. The third element, the measuring apparatus, is fixed adjacent to the jointing of the two arms, and comprises a roller reading to the thousandth part of its circumference, being divided into 100 parts, and having a vernier. An endless screw is cut on the roller axis, and engages with a worm wheel of ten teeth, by which the number of revolutions of the roller is recorded. The area of the swept figure is not measured directly, for that is what the instrument is designed to avoid. But the surface swept over by the upstroke, subtracted from that swept over by the downstroke, gives the area of the figure measured. The subtraction is effected by reading off the counting wheel and index roller before starting, and again at the termination, and subtracting the first reading from the last. But this is only a general expression, since the estimation is modified by whether the needle point is outside or inside the figure traced, or whether the wheel has gone through more than one revolution forwards or backwards.

Planing.—*Metal.*—The removal of metal by means of reciprocating tools with single cutting edges, in machines with horizontal, or vertical movements. Generally the work done is restricted to absolutely plane surfaces, though in exceptional cases the rectilinear movements of the work in one direction are combined with curvilinear movements in a direction at right angles therewith. The work of planing, though dependent to some extent on the type of machine used, embodies essentially two important matters—the proper fixing of the work, and the most suitable method of cutting.

Fixing and Clamping.—Two principal cases exist, with infinite gradations between, that of heavy, and that of light, flimsy work, and the methods of securing each to work tables vary accordingly. In the first there is no risk of springing, but in the second, direct clamping in opposition to the table will spring a slight elastic piece unless the lower face has been already made true. In such cases, the clamps must be tightened in opposition to packing pieces, such as thin strips or wedges, or the pressure must be made laterally, the choice depending on the nature of the piece of work. Moreover, the clamps have to fulfil two functions, one the holding, the other that of

affording resistance to the cut of the tool. In many cases, generally in all heavy work, the two are combined in one and the same individual clamps. But in the lighter articles that are liable to spring, it is often better to clamp lightly, and to provide something else to resist end pressure. Thus, bars or plates are bolted to the table in front of the work, or are pinched laterally against it, or the thrust is often taken by a common angle plate bolted to the table. When the risk of springing is great, as in some thin pieces of work of large area, it is good practice, after having taken a roughing cut, to relieve the pressure by slackening the clamps and tightening them again with less force, or by repacking before tightening, if the surface is found to have sprung out of level.

The level tables of the planing machines are most valuable aids to setting work by. Scribing blocks, squares, and various gauges are readily worked from its face, giving facilities for setting parallel and square. The top of a piece of work is commonly levelled by the turned-down end of the scriber, moved across its face, the base sliding over the table, or over a parallel strip laid upon the table if the height of the scriber is insufficient. Bottom faces can be similarly levelled. Horizontal centres and centre lines are tested with the point of the surface gauge. Surfaces are also tested by a straightedge and the insertion of a caliper, or a thickness piece, or a rod gauge between the lower edge of the straightedge and the table. Vertical faces are checked with a square.

The angle plate is a valuable adjunct to the planer, not only as an abutment, but for bolting awkwardly shaped pieces against, which could not be attached to the table without involving packings. It is as valuable on the planer as on the lathe, and for the same reasons.

Short pieces of work are done either on planer, or shaper. It is not desirable to put small single articles on the planer, but where a number can be arranged in line, the planer affords the greater economies. The methods of attachment must vary with the class of work. Some pieces are bolted directly to the table, others to an angle plate.

Methods of Cutting.—The ordinary straightforward tools are mostly used for planing operations, the side-cutting tools of the turner being in little request for upper surfaces. But these are employed much when side-cutting and under-cutting have to be done, involving vertical and angular faces. The amount of cranking necessary may be considerable when the cutting has to be done from the tool box on the cross-rail. The tool boxes on housings are more advantageous for side-cutting. If these are not present, it may be necessary in deep work to reset it in order to bring the side or sides uppermost.

The distinction between roughing and finishing has to be made. Only in the commoner classes of work, such as fitting brackets to facings, is a single rough cut sufficient. It is not enough for faces which have to move over one another, nor for those in which the demands of fitting have to be accurate within fine limits. The majority of planed surfaces therefore require a finishing cut following the roughing, and for the best results three cuts are often desirable, because much work is liable to spring and alter in shape on the removal of the skin by roughing, and the finishing cut alone is not then sufficient for fine correction.

The depth of cut, and lateral feed, and speed are subject to great differences, not only in respect of different metals and alloys, but practice has been changed due to the advent of the high-speed steels. There is no advantage in giving approximate figures, as these vary with differences in texture, hardness, or softness, light or heavy pieces, the amount of overhang of the tool, and so on. As with turned work, the roughing and finishing cuts are radically different. Deep cuts and moderate feeds are adopted for roughing, and very shallow cuts and broad feeds for finishing. The planer is not properly adapted for any cutting but that on an exposed surface. All under-cutting is more or less troublesome, but much of it has to be done. Sometimes special cranked tool bars are used, clamped in the tool box, and standing out, a dodge used in planing keyways in bores.

A feature of planing is that the cut must terminate at the moment of reversal. This makes it impossible to plane up to a shoulder. The tool must be allowed a little freedom of

travel, of from $\frac{1}{8}$ in. to $\frac{3}{4}$ in. beyond the end of the surface to be planed. A groove has therefore to be cut across, or a hole drilled if a narrow cut, such as that for a groove, is taken. Most pieces of work permit of letting the tool travel beyond the end. If a horizontal and vertical face adjacent have to be tooled then the work must be turned and reset with the vertical face longitudinally on the table.

One of the most useful adjuncts to the planer is the **Machine Vice**, of which there are several designs. In all the best, provision is made for exercising a downward thrust, to bed the work down, at the same time that clamping it in the jaws is effected. Some vices have swivel jaws to clamp pieces that are not parallel. A tilting table is often used to hold pieces of work with faces that have to be tooled at definite angles. In the most complete designs graduations into degrees are made, and the table rests on supports when in the horizontal position. Planer centres of various kinds are used for setting pieces for angular work. The latter is carried between the points of the centres and set with an index pin in suitable holes. **Vee Blocks** of various kinds are used by the planer hand for supporting circular work, as shafts, bossed portions of castings and forgings. Numerous forms of clamps are used for holding down the work on the blocks. **Packings** are used for carrying pieces clear of the table. They are thin or thick, of various depths to afford support at different heights. In some cases wedge packings are used, and they are sometimes graduated down the edges to indicate the vertical height of the adjustments.

Planing—Wood.—Wood is planed both to make its surface smooth, clean, and true, and to reduce it to a given thickness. Ordinarily one side is first planed true, and the required thickness gauge-marked with a gauge working from the trued face, and then the other side is reduced to the gauge lines. Edges and ends are planed square with these faces by testing with a try square. In this case also one edge and end are first squared and then the required width and length gauged or measured from them. If the finished sizes are definitely fixed, a piece of wood must be selected and sawn large enough to hold up to those dimensions when reduced by planing and squaring up accurately. A warped piece of wood requires more allowance for this than a piece comparatively true, which merely requires cleaning up and the removal of the roughly sawn surface. Very thin and wide pieces of board curve so easily that they can rarely be planed true on one side and gauged to thickness, but must simply have their rough skin removed and be kept straight and flat by their attachment to stiffer parts of the work they are used for. Thicker pieces that are curved and warped may often have some of their inaccuracy removed by keeping them forcibly bent the opposite way for several hours or days, and exposing a convex face to the air or fire, and damping a hollow face.

In planing, the front edge of the wood presses against the bench stop, and the plane is pushed over its surface in strokes as long as the arm can conveniently make, generally with more or less downward pressure on the plane. If it is merely a case of removing a rough skin, the thickness of one shaving is taken off uniformly all over the surface. If some parts stand higher and require reducing more than others an increased number of shavings are taken off accordingly. The surface is tested first by the eye and after with straightedges, or winding strips if the length is great. With one face and edge planed true and square with each other, the remainder can be done by working to lines gauged or measured from these. The plane is usually worked in the direction of the grain. When used transversely or diagonally, and especially when used on end grain, precautions must be taken to prevent the cutter from splitting the wood away at the farther edge. This is usually done by bevelling the edge down to or a little below the level the surface is to be reduced to, and using the plane carefully at the finish.

Planing Machines.—*For Metal.*—The planer is one of the oldest machine tools, following the drill and the lathe. It was invented by Roberts about 1820, and the original machine, with chain-driven table, may be seen in the South Kensington Museum. Fox and Clement divide the honours with Murray and Roberts, 1814-1820. The chain gave place to the rack

drive, alternatively made square, or as a stepped gear, or a helical gear. Later, the long screw working in nuts, and the worm working in a rack have divided favour with common rack movements, but the latter is still retained on by far the largest number of machines made.

The elements of the planer are the following. The bed, made of box section, with box cross-girts, and having either flat, or vee'd ways for the table on which the work is carried to slide along. Both designs of ways have their advocates, and both are made in about equal numbers, and theoretical objections to each have no weight in practice. The table must be massive in order to avoid risk of lifting under heavy cutting. Where vees are used they must be sufficiently steep to avoid side slip of the table. Lubrication is provided by wooden rollers floating in oil baths in the bed.

The cross-rail on which the tool box is carried and fed horizontally has vertical adjustment on the uprights, termed *housings*, which stand out beyond the sides of the bed sufficiently to leave the full width of the table available for carrying work. The capacity of a planer is given as the length of stroke of table, the width carried between the housings, and the height from the table to the under side of the cross-rail. The housings are bolted against wings on the sides of the bed, or on top of them. What is termed the *parabolic* form of housing is commonly adopted. The cross-rail is adjusted vertically on the facings of the housings by means of screws actuated by bevel gears at the top. In the larger machines these are actuated by belt power. The housings are tied together at the top with a cross-bar, which is often curved backwards to allow the hand-wheels of the tool boxes to clear when the cross-rail is at its maximum height. The cross-rail has no feed, but the down feed is imparted to the tool-holder slide, and the transverse feed to the tool box bodily. The feed is derived from the reversals of the table, through tappets adjustable along one edge of the table, and the tappets also cause the reversal of the table to take place. The driving and reversal of the table was formerly always done by nests of gears, usually lying within the bed, the last pinion which drives the rack being of small size. Improved methods of driving, using a large rack wheel, and with reversing gears outside the bed, are becoming common. Tool boxes are carried on the cross-rail, one, two, or sometimes three in number, and in many machines one on each of the housings. These are actuated by a feed screw which imparts the linear traverse feed of the box bodily, the screw working in a nut at the back of the saddle or carriage, and by a splined feed rod which actuates the down-cutting feed through bevel gears. In all boxes the tool holder has provision for setting to a few degrees on each side of the perpendicular, to permit down-cutting on the deep sides of work, without which canting the tool box would not clear the sides being cut.

The driving mechanism varies much in different machines. The older device was a loose central pulley flanked by the pulleys for driving and return, and actuated by a single belt always running in one direction, and thrown over on the outer pulleys in turn, the outer pulleys having twice the width of the middle one. A better design provides distinct sets of fast and loose pulleys for driving, and for returning, the latter being the smaller of the two. The rack may be retained, or a screw drive substituted. Generally the pulleys are on one side of the machine, except when a screw is used, in which case they are placed at the rear end. From this broad design of planer a large number of variations have been made, most of which are described elsewhere. *See* **Open-Side, Plate-Edge, Pit, Side,** and **Vertical Planing Machines,** respectively. Also **Quick Return,** and **Tool Boxes.**

The principal differences in the older and the present-day machines are: heavier framings, with more economical distribution of metal; accelerated rates for cutting, and higher ratios of quick return; cushioning devices for avoiding shock at the moment of reversal; improved mechanical devices for belt shifting; better arrangements for putting on and regulating the feeds; improved tool boxes; and the increased use of double-cutting tool boxes. Lastly, the growth of new kinds of machines of special designs adapted to various kinds of work.

Fig. 90 illustrates a high-class planer by Cunliffe & Croom, Ltd. It is characterised

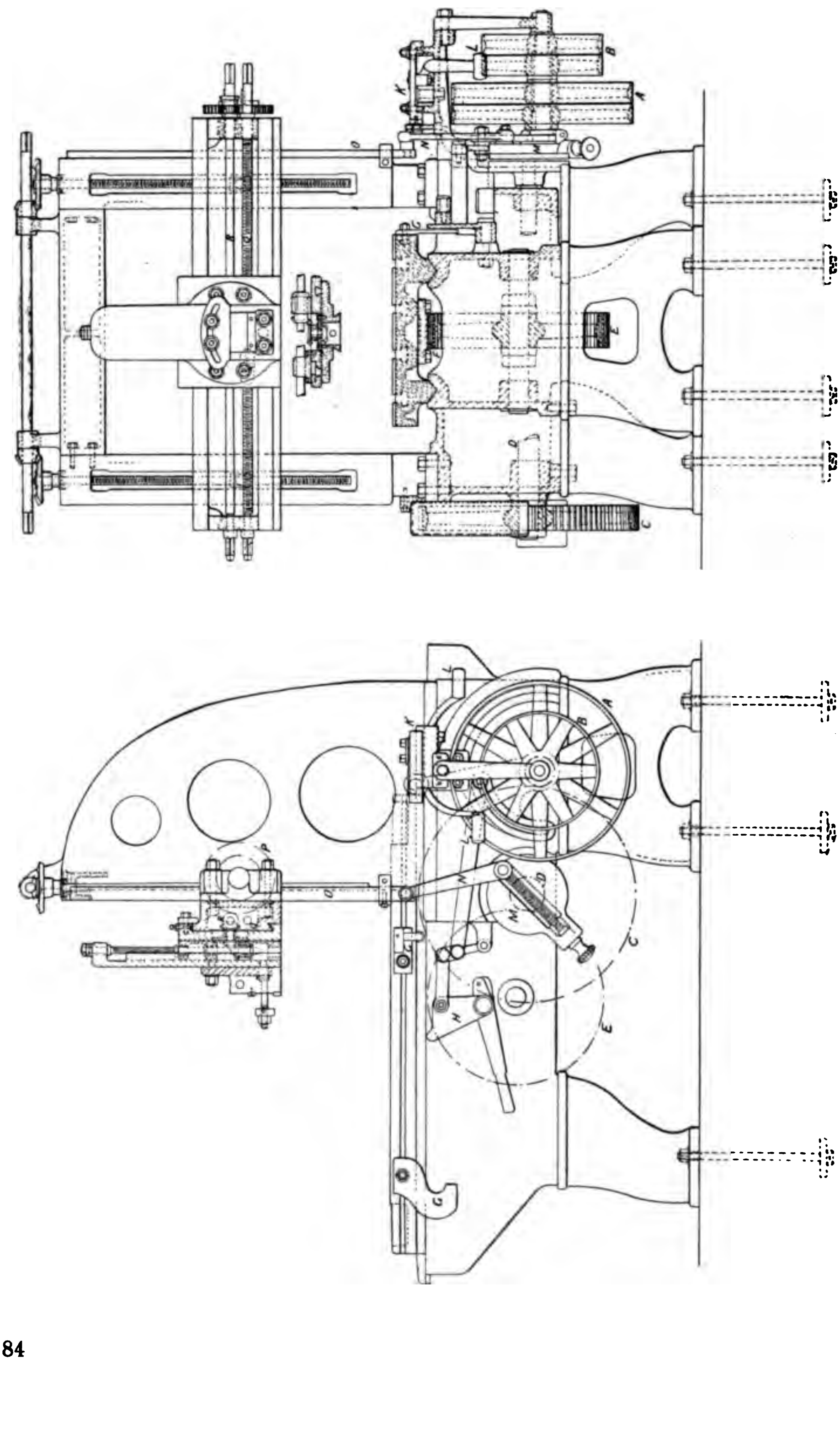


Fig. 90.—6 ft. × 2 ft. 6 in. × 2 ft. 6 in. Planing Machine. (Cunliffe & Croom, Ltd.)

by a departure from the common type of machine in which the gears for quick return are enclosed within the bed, and which are clumsy in their operation, and in which the belt is shifted over the loose pulley for reversal across a distance equal to twice its width. This involves waste of time, and of power, and is noisy.

In the machine shown there are two belts, and two pairs of pulleys, fast and loose; A for the cutting stroke, B for quick return. In this particular example the cutting speed is 21 ft. per minute, and the return 67 ft. per minute. But the latter can be increased by substituting a pulley of a different size to that furnished for the countershaft. The pulley shaft goes through the bed, and carries a pinion at its opposite end driving a large wheel C on a shaft D, which has at its other end a pinion engaging a large wheel E, which gears with the rack F on the bottom face of the table. The use of a large rack wheel instead of the small pinion formerly universal is an important feature in steady driving, avoiding risk of lifting the table, and lessening chatter, because more teeth are in action at one time. The American machinists term this the *bull* wheel.

The striking gear is a feature that differs from the older types. It is shown in Figs. 90 and 91. The tappets G, G on the edge of the table strike over the lever H in opposite directions. The various lever connections seen impart a linear movement to the plate K, the movement being controlled by two slots which slide over stud bolts in the casting which carries the pulley bearings. The plate K has a cam groove which coerces the pins of the levers that operate the two belts. A very slight movement in the slot suffices to shift the belt fork ends L, L, by the amount required for throwing over the belts.

The feeds are derived from the driving shaft. The feed disc M is keyed on the shaft at the opposite end to the wheel C. The amount of feed is regulated by the adjustment of the pin of the operating lever N across the disc from zero to $1\frac{1}{2}$ in. in both directions. The drive takes place to a rack bar O which is connected to the feed gears on the end of the cross slide. The rack drives a pinion on the same shaft as the wheel P, and the latter drives either

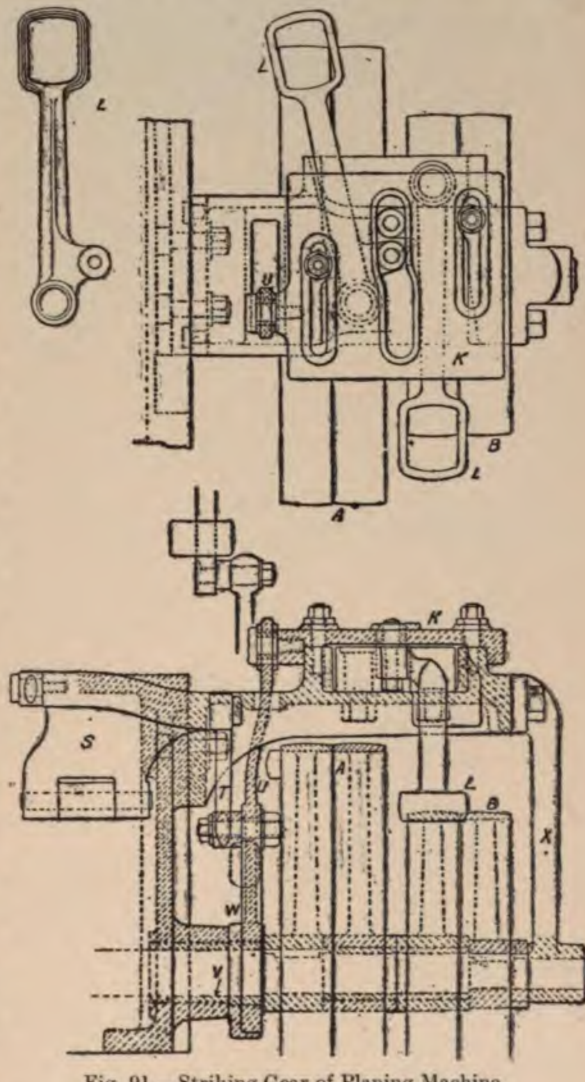


Fig. 91.—Striking Gear of Planing Machine.

to the screw Q for the cross traverse feed, or to the splined shaft R for vertical feed. Pinions of equal size are used for both. The feed takes place from the pinion to a ratchet wheel which actuates a spring pawl that imparts a partial rotation to the loose wheel P, which then feeds

either the screw or the splined shaft. The feed disc H is shown enlarged in Fig. 92. It acts by the friction of a leather disc between

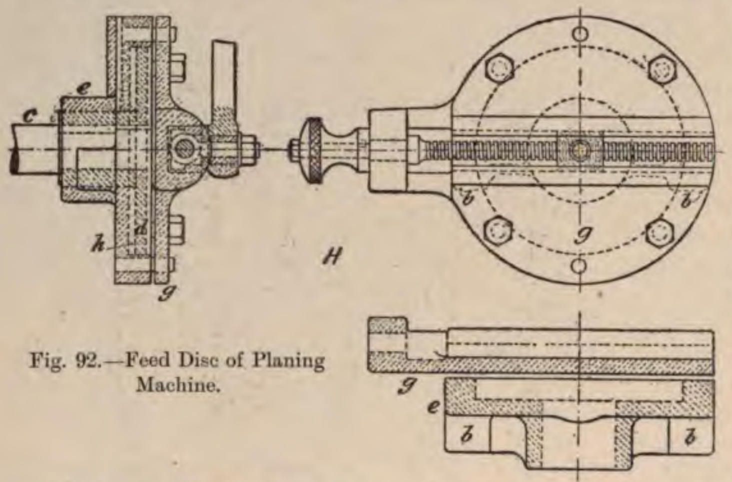


Fig. 92.—Feed Disc of Planing Machine.

opposite faces. It slips on reversal. When reversed by the rack its horns strike the stop, and so slip. The driving pinion on the shaft D, Fig. 90, is carried on the shaft lettered *c* in Fig. 92, to which the disc *d* is keyed. The boss of *d* is encircled by the boss of the body *e* of the feed disc, on which it runs freely. The disc *g* is pinched against *e* with four set-screws, leaving a space between *g* and *e* which allows of regulating the degree of friction between the faces of *d* and *e* and the leather washer *h*.

Another feature of this machine is the provision for bringing the driving belt on at an angle. A lug standing out from the side receives the fork of the lever S, Fig. 91, and S is connected with the lever T, which is pivoted to the lever U attached to the striking plate K at one end. At the other end it is pivoted on the shaft V on which the driving and reversing pulleys are attached. The lever U carries an extension W of quadrant form, in the slot of which the lever T can be clamped, so sliding the striking plate K. It is obvious, therefore, that the operation of the striking lever is unaffected by adjustments in the angle of the striking levers. The bracket X which carries these is pivoted around V and is clamped by its bolts in a slot.

Cushioning Devices.—The Smith & Coventry method is shown in Fig. 93. The driving shaft A is driven by the wheel B which runs loosely on it, but which is driven from a clutch E, feather-keyed to the shaft; and being slid thereon, is engaged with or disconnected from a clutch F which is secured to the loose wheel B. At the back of E there is a strong coiled spring which is in contact with E on one side, and with a nut D at the other. When the clutches E and F are forced apart, the spring is compressed, and the spur wheel drives

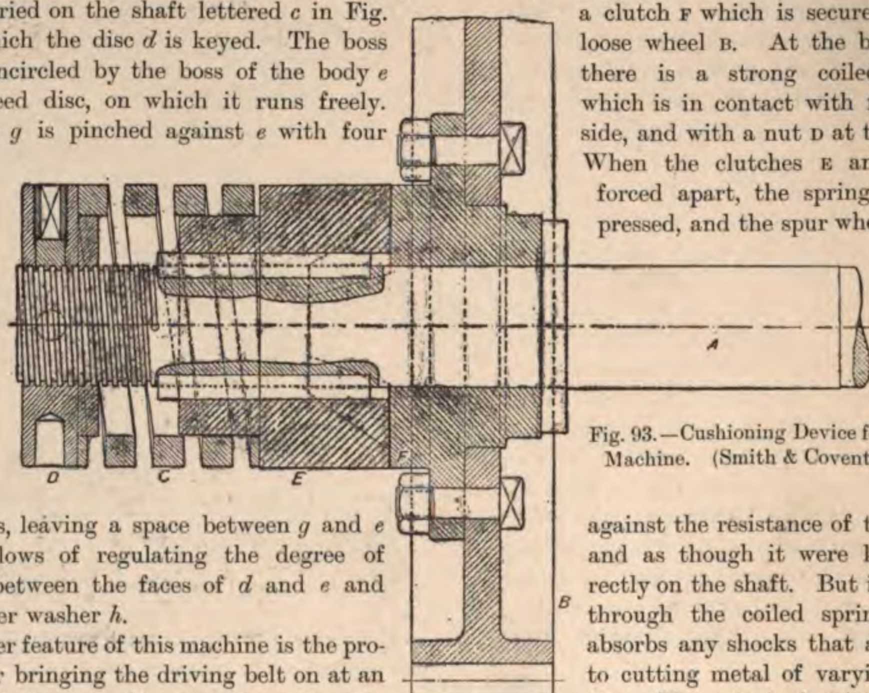


Fig. 93.—Cushioning Device for Planing Machine. (Smith & Coventry, Ltd.)

against the resistance of the shaft, and as though it were keyed directly on the shaft. But it does so through the coiled spring which absorbs any shocks that arise, due to cutting metal of varying qualities. The principal point is, that at the termination of a cutting stroke, when reversal takes place, and the wheel is not driving for an instant, the spring, by forcing the

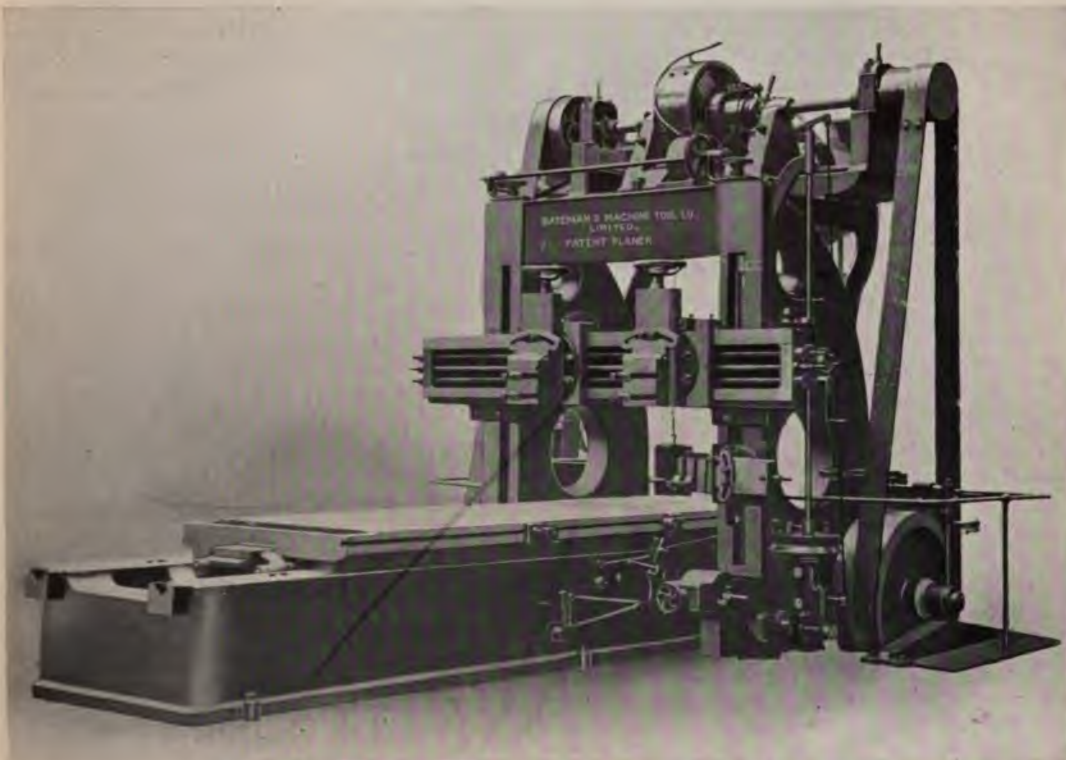


Fig. 95.—Electrically-Driven High-Speed Planing Machine.
(Bateman's Machine Tool Co., Ltd.)

Fig. 100.—16-in. × 6-in. Wood Planing Machine. (A. Ransome & Co., Ltd.)

To face page 86.

sliding clutch E against the clutch F on the wheel, starts driving the clutch in the direction for return. The spring thus acts as a buffer at the moment of greatest stress, and assists the reverse.

The cushioning arrangement of the Bateman planers is shown in Fig. 94. The buffer action takes place in opposition to the driving rack wheel. The rack is not bolted to the table in the usual way, but slides in grooves, and has its movements controlled by sets of springs at each end of the rack. The rack A in Fig. 94 is connected through a cross-head B at one end, and spring rods C, C to the springs D, D, and E, E. The springs D receive and absorb the shock when the table is reversed at the end of the cutting stroke, and the springs E receive it when the table comes to the end of its return stroke. F, F are the spring rod guides, and serve as abutments for the springs D, D. The lugs G, G form abutments for the springs E, E. The degree of compression of the springs E, E is adjusted by the screwed sleeves J, J.

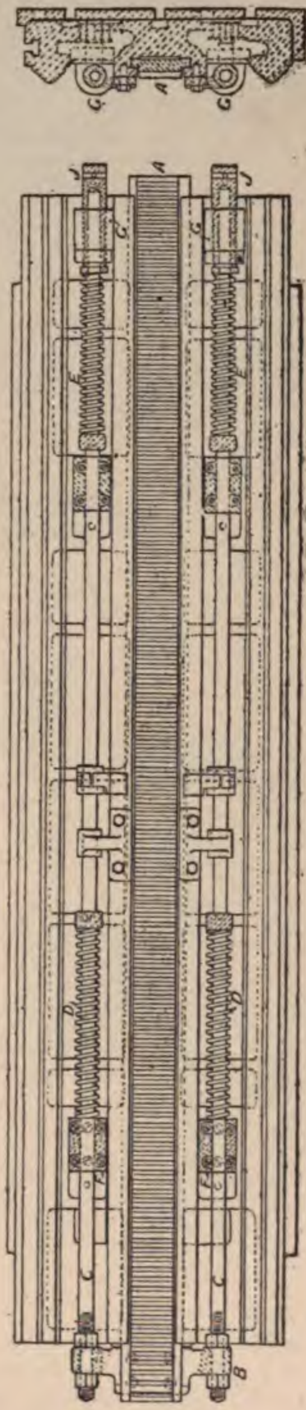


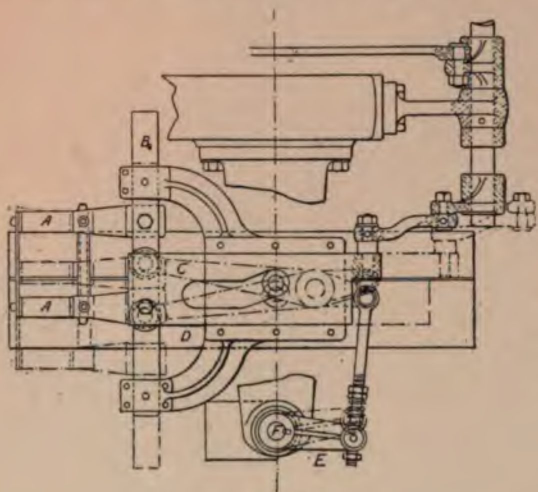
Fig. 94.—Cushioning Device for Planing Machine. (Bateman's Machine Tool Co., Ltd.)

Fig. 95, Plate VII., shows a Bateman planer, arranged for motor drive, the motor being mounted above and between the housings. Its spindle drives directly to the small and large pulleys at opposite ends, giving the belt drives down to the pulleys at either side of the bed, for cut and return. In the belt-driven machines, in which the place of the motor in Fig. 95 is occupied by fast and loose pulleys, a change-speed mechanism is included, comprising sliding spur gears by which three rates of 20 ft., 60 ft., and 80 ft. are obtained. This is rather unusual, as yet, in planers, the single-speed being generally deemed sufficient. When a motor is employed, Fig. 95, it is of variable speed type, giving also three rates. The following table gives particulars of speeds obtained on the Bateman planers. The term "cycle" means one cut, and one return of table, so that the time of a cycle equals time of cut and of return added together.

Size of Planer.	Stroke.		Time of 10 Cycles.		Feet in 10 Cycles.	Average Speed.	Max Speeds (Ft. per Min.).		Mean Speed (Ft. per Min.).	
	Ft.	In.	Min.	Sec.		Ft. per M.	Cut.	Ret.	Cut.	Ret.
24 in. × 24 in. × 6 ft.	6	3½	1	8	126	111	80	225	78	210
36 in. × 36 in. × 12 ft.	12	0	6	0	240	40	20	175	20	160
(With 3-speed gear	12	0	3	34	240	67	40	175	40	160
box for cut) -	12	0	2	46	240	87	62	175	60	160
42 in. × 42 in. × 20 ft.	22	6	6	39	450	68	45	145	44½	141
42 in. × 42 in. × 14 ft.	14	0	3	56	280	71	50	155	48	147
60 in. × 60 in. × 12 ft.	13	0	4	8	260	63	42½	140	42	127

The Bateman style of belt fork drive is shown in Fig. 96. The fork rollers between which the belt runs are shown at A, A. The forks are attached to the sliding bar B, and actuated

by the lever C. The full and dotted outlines indicate the two extreme positions. The cam roller which actuates the sliding bar B, receives the roller fitting in the cam slot in the plate D,



and actuated by a tumbler at the side of the bed. The reversing lever C is double-ended. It is prolonged at the hinder end of its pivot, and actuates through a spring rod the lever E, which is keyed on the upper end of a vertical shaft F. This lever E actuates a friction clutch which connects the loose pulley H, made heavy to serve as a flywheel, with the fast pulley J. Teeth cut in the lower end of the shaft F engage with teeth cut in the sleeve G which slides on the driving shaft without rotation. A ring entering a groove turned in the boss of the fast pulley H forms this connection. The slight rotational movement given to the shaft F suffices to make or break frictional contact between the pulleys H and J, which is made to occur simultaneously with the reverse of the table. The belt is wider than the width

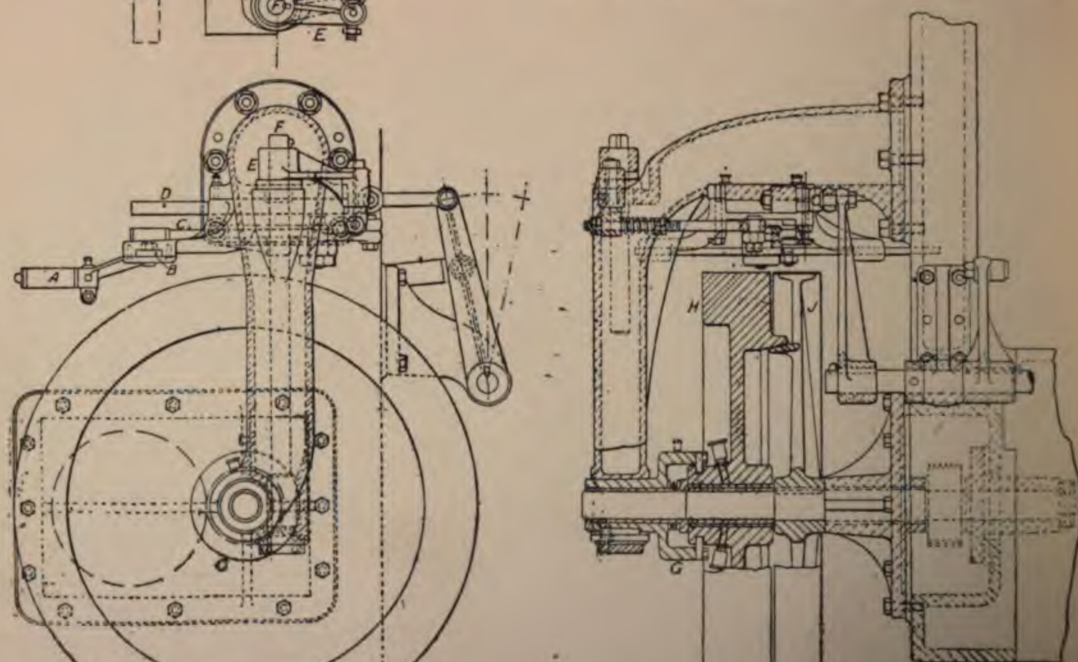


Fig. 96.—Belt Fork Drive for Planing Machine.

the linear motion of which in its guides shifts the roller and throws over the lever C and the bar B. The linear motion of the cam plate D is received from levers and links seen in the views,

of the fast pulley J, and the
the loose pulley H, so receiv
some of the energy whi
flywheel pulley at the m

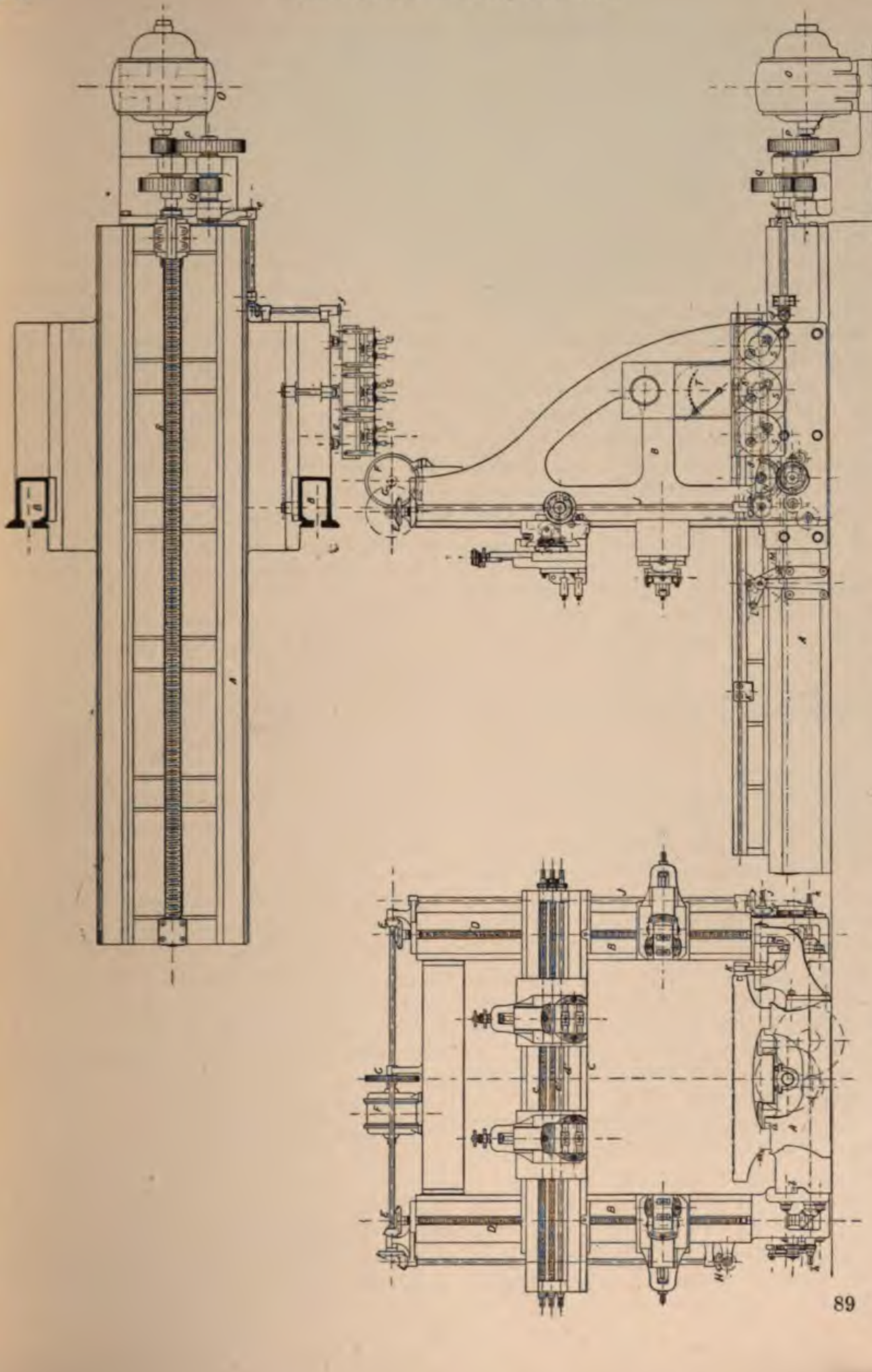


Fig. 97.—Electrically-driven Planing Machine. (Messrs Sir W. G. Armstrong, Whitworth, & Co., Ltd.

return rate of travel of 210 ft. to 230 ft. per minute is obtainable by means of the sliding rack and flywheel friction clutch arrangements. Formerly planers were only constructed to have one speed of cutting, and this had to be employed for all metals and alloys. Several machines are now made with a range of speeds.

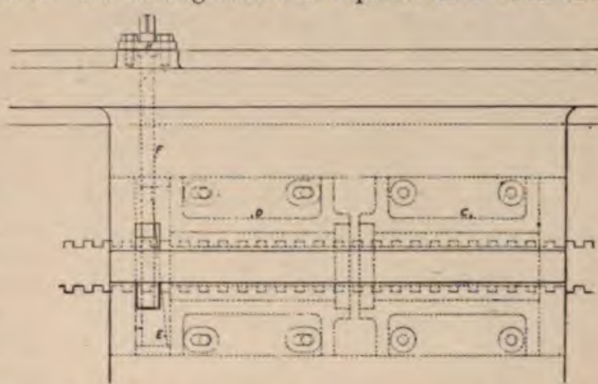
Tool Box.—The ordinary planer tool box is built in nearly uniform designs. The back or saddle slides along the cross-rail and carries on its face a swivel plate, capable of swivelling and being bolted through a large angle, and on which the tool slide is moved along vee'd edges by the feed screw. The actual tool holder is hinged to this slide, the clapper allowing the tool to lift on the return stroke. The feeding of the screw is unaffected by alterations in the angular position of the tool box, because the bevel gears through which the motion is transmitted are attached to a sleeve, around which the tool box swivels. These are driven by the bevel wheel which is key-grooved to the feed shaft, travelling with the tool box as the latter is driven by the feed screw that runs parallel with the feed rod. The bevel wheel on the feed screw of the tool box is thus moved vertically and at a rate determined by the setting of the feed by ratchet or feed disc.

Double Cutting. — The disadvantages incidental to the non-cutting return stroke are partly overcome by the method of double cutting, or by the acceleration of the return stroke, the latter of course being only done when the single-cutting tool box is retained. As a rule the acceleration method is embodied in modern planers, but nevertheless a fair number of machines are fitted with mechanism for cutting on both strokes. In the original of these, the Whitworth "Jim Crow," a single tool is carried in a rotating holder, and is turned round through 180° after each cut. In the later types, two tools are used, set back to back, and carried in a tilting tool box, which, bringing either tool into action, lifts the other clear of the surface of the work.

An electrically-driven planer by Messrs Sir W. G. Armstrong, Whitworth, & Co., Ltd., driven by a 20 HP. reversible motor, by Messrs Vickers, Sons, & Maxim, Ltd., is shown in Fig. 97. It is of large dimensions, taking 12 ft. × 6 ft. × 6 ft., and is therefore attached directly to its foundations without feet. The bed A has flat ways, with a take-up strip *a*. The housings B, B are bolted to the sides of the bed, and pulled down with a key *b*. There are four tool boxes, two on the cross-rail C, and one on each housing. The cross-rail is elevated by the screws D, D, actuated through the bevel gears E, E, from the motor F on the top stretcher, the speed being reduced through gears G. Hand-elevating gear is connected up from H. *c*, *c* are the two longitudinal feed screws to the two tool boxes, and *d* the down-feed rod common to both. These are actuated by the vertical feed rod J, driven through bevel gears from the dogs K, K, tappet L, rod M, quadrant gear N, to a wheel on the first bevel wheel shaft. The effect of each reversal by the dogs and tappet is to turn the feed rod J through an arc of a circle, and cause it to actuate the feed gears which operate *c*, *c* and *d*.

The driving motor is shown at O. It is of variable speed compound wound type, reverses automatically, and drives through the two pairs of gears P and Q to the table screw R, 5 in. diameter, four-threaded, 5¾ in. pitch. S, S, S are special switches mounted on the side of the planer, worked from the driving gears through pitch chains shown at *e*, *f*, *g*. T is the variable speed switch actuated by the attendant. The functions of the switches S are to start the motor after it has come to rest at the end of the stroke; to insert or withdraw resistance in series with the field coils, thus altering the speed after reversal; to reverse the armature connections, and thus reverse the direction of rotation; and to retard the armature at the end of the stroke by strengthening its field prior to reversal. The speed variation of the motor is produced entirely by varying the shunt current. The efficiency of the motor is not less than 87 per cent. under any circumstances. The range of speed of the motor is from about 300 to 900 R.P.M. It runs at any speed between 300 and 900 on the cutting stroke, according to requirements. When the motor reverses automatically at the end of the stroke, a resistance is automatically inserted in the field, quickly

raising the speed to 900 for the return stroke. At the end of the quick return stroke, immediately before reversal, the field resistance is short circuited, providing a strong field for reversing in. The motor then reverses and takes its slow-cutting stroke. The centre switch s is used to start or stop the planer; *h* and *j* receive handles for hand adjustments of feeds, &c. The speed of cutting can be varied instantly between the limits of the slowest cut and of the quick return. The variation can be made by small intervals, and without altering the speed of quick return. This variation of cutting speed is a valuable property. The reversal is also rapid, so that planing can be done up to a line. An armour-plate planer of 24 ft. × 12 ft. × 10 ft. capacity at Messrs Vickers' works at Sheffield, fitted with one of these reversing motors, was worked twenty-four hours a day for over six months. On short stroke work it frequently had to reverse over 6,000 times a day, yet at the end of six months, the motor and switches had not deteriorated in the least. The cost of belting in that time on an ordinary planer of the same size would have been from £30 to £40.



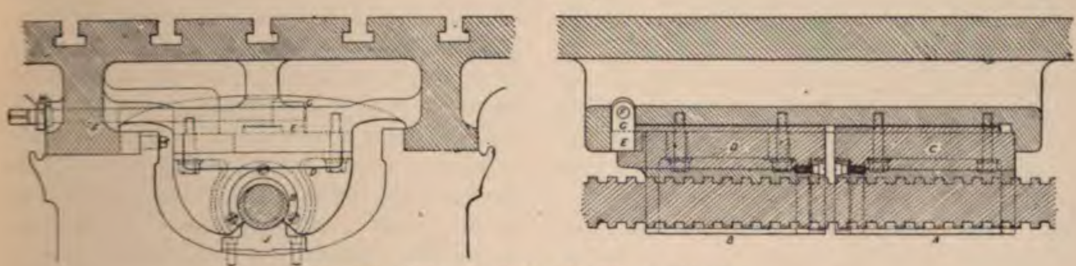


Fig. 98.—Whitworth Nut for Planing Machine.

Whitworth Nut.—Fig. 98 illustrates the Whitworth planer nut. It is made in two portions, A, B, with provision for endlong adjustment. One half-length is bolted by its body casting C to the under side of the table through round holes, the other half through slot holes in D, which last permit of adjustment of the half-length of nut. The nuts and screws therefore bear on the faces which are farthest opposed to each other. The adjustment is made by the long wedge E, which is fitted between the nut and a shoulder on the under side of the bed. It is pulled up by an adjusting screw F, and block G, which is a part of the wedge. A collar, H, confined by a flange bolted at the side of the bed confines the screw endwise. The screws being tightened in their slot holes, hold the nut securely. J is one of the supports for the driving screw.

Power Absorbed.—It has been proved by the experiments of Captain Tresidder which were made at the works of John Brown & Co. in 1900, that little more power is absorbed during the cutting stroke of a planer than when the machine is running idly. The greatest stress occurs at the instant of reversal, when about twice the power is required than when cutting.

RACK-DRIVEN MACHINE; cutting speed, 10 ft.; return, 16 ft. 8 in. per minute; table loaded with plate, 20 tons, eight tools surfacing. Cut, $\frac{5}{16}$ in. to $\frac{3}{8}$ in.; feed, about $\frac{1}{50}$ in. per traverse:—

	HP. Momentary at Start.	HP. During Stroke.
Cutting stroke, tools disengaged	16½	6 to 7½
Cutting stroke, cutting	...	9 to 10½
Return stroke	18	9

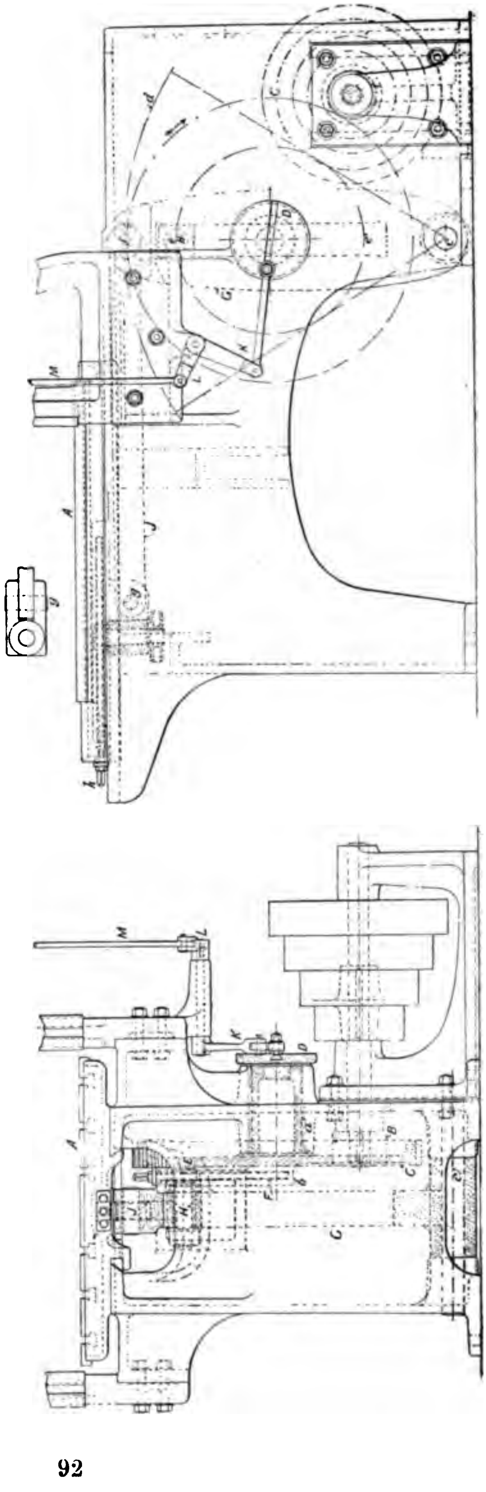


Fig. 99.—Crank Planing Machine. (Greenwood & Batley, Ltd.)

Heavy Double Screw Planing Machine, 14 ft. 8 in. between standards; cutting speed, $10\frac{1}{2}$ ft.; return, $14\frac{3}{4}$ ft. per minute.

	HP.	
Table, about 25 *tons, empty*—	Momentary at Start.	During Stroke.
Cutting stroke - -	$22\frac{1}{2}$	$7\frac{1}{2}$
Return „ - - -	24	12
Ditto, with 8-*ton Plate*—		
Cutting stroke - -	24	12
Return „ - - -	$25\frac{1}{2}$	12
One tool cutting - -	24	12
Running shaft only -	...	5
Running idle pulley on countershaft - -	...	$1\frac{1}{2}$

Crank Planing Machines.—These are very useful and popular for small work, the length of which does not exceed about 30 in. They are planers driven with the essential shaper quick return mechanism, and therefore they plane to an exact length. Elliptical wheels are used in some machines, the Whitworth quick return in others. One of these is illustrated in Fig. 99, by Messrs Greenwood & Batley, Ltd. The table A is fitted with flat slides to the bed, and confined laterally by vee'd edges, one of which has a take-up strip. It is driven from the four-stepped cones. On the cone shaft is a pinion B, which gears with the large spur wheel C. This wheel is carried at one side only by a large hollow cast boss *a*, which forms its shaft, and which has its bearing in a long boss cast with the bed. The boss *a* carries the feed disc D. On the opposite face of the wheel there is a slotted piece *b*, along which a die block E can be adjusted radially by a screw F, to vary the length of stroke of the table. As the wheel C revolves at a uniform rate the difference between the cutting stroke and the quick return will be the greater the larger the radius at which the die nut E is set. This is clear, because the link G in which the pin H and the die block slide during the rotation of the wheel C is pivoted at *c*, and rocks in the arc *d*. The pin H when at *e* will be moving at its slowest, and when at the other extremity of its path *e′* at its swiftest. The table will partake of this variable motion, being connected with

the top of the link G by the connecting rod J at *f* and at *g*. The screw *h* is for the adjustment of the table and work in relation to the tool box. The feed disc D is connected by the levers K, L to the feed rod M, which goes to the end of the cross-rail.

Planing Machines—for Wood.—These include several types for heavy roughing, and for fine finishing. In the majority of cases revolving cutters act upon the surface of the wood, but in some instances fixed knives or cutters are used to produce a very smooth finish. But a fixed knife will only work properly when the timber is propelled at a fast rate, and it is impossible to feed the wood with four cutters in action, so that the fixed knife is usually confined to operating on one face of a board.

The simplest planers are the *hand* or *surface* planers, which have a revolving cutter cylinder running between the two portions of a table, upon which the wood is slid and pressed down by hand. The first table is set lower than the other by the amount which has to be planed off. The timber is taken out of wind and made perfectly true and straight, ready for jointing, or further planing on the other side. The surface planing and *thicknessing* machines differ from the jointers in having feed rollers, by which the stuff is fed along a table, under the revolving cutters; the height of the table being varied, the thickness of wood is thus controlled. Any number of pieces may be planed to uniform thickness. Pressure bars are placed in front and behind the cutter to hold the timber down closely, and prevent the grain from tearing out. The feed motion to the rollers is arranged to give several different rates, to suit the depth of cut, and class of timber being planed.

The hand and thicknessing machines are combined in one for small shops which do not require to have two separate machines, the upper or jointing table being located above the cutter cylinder, and the thicknessing table below. Double-cutter machines work with cylinders both above and below the wood, to finish the two faces simultaneously. Side cutters are also applied when required to finish the edges, with tongues or grooves, &c.

Very heavy work is planed upon trying-up machines, which somewhat resemble the metal planer in form. The balk of timber is clamped upon a long table, which is fed along a bed below the revolving cutter cylinder, the bearings of which are carried in a slide adjustable on uprights. In some machines the cylinder is replaced by a large horizontal disc with knives inserted; this produces a very true surface, but is rather slower in action than the usual cylinder.

In the more complex planers which are employed for finishing flooring and other boards at one pass, Fig. 100, Plate VII., the board is fed in through rollers until it encounters a bottom cylinder, which roughs off the under side. The feed is effected by large rollers the height of which can be adjusted to suit the thickness of stuff. The latter then passes on to a fixed knife which smooths the under face and gives a fine finish. The top is then planed at a further stage with revolving cutters, and just after the edges are planed, tongued, grooved, or beaded with vertical side cutters. Variations in this general arrangement are made, some machines having five revolving cutters, and fixed knives for finishing all four sides, in the case of flooring boards. As the fixed knives dull rapidly, an arrangement is included for withdrawing one or more of them in a drawer, to be replaced by freshly sharpened knives. The rates of feed in these machines are high, up to as much as 200 ft. per minute.

Lightning planers are a small type in which the stuff, principally thin small strips and boards, such as for boxes, are shot over a fixed knife by a large rubber-covered roller; the cut is light and the finish very high, equal to a polish.

Planishing.—The finishing of copper sheets by a process of hammering and polishing. It comprises smoothing down irregularities left after razing down wrinkles, hardening and closing the grain, and imparting a hammer polish preliminary to the application of polishing powders. The hammering is done by a succession of blows in line, or in circles, according to the shape of the work, the blows overlapping in the courses. Light finishing blows are imparted with a piece of parchment drawn tightly over the head.

Planishing Hammers.—Coppersmiths' hammers of from 1 oz. to 3 or 4 lb. weight, used for smoothing copper goods. *See* **Hammers.** The faces are flat, convex, and bullet, concave, and grooved, or saddle faced, to suit the various shapes of the articles to be operated on. *See also* **Pneumatic Planishing Hammers.**

Plano-Milling Machines, or **Slabbing Machines.**—These are built on the general designs of the common planer, and deal with much the same class of work as this machine does. They have a bed, sliding table, housings, cross-rail, and cutter spindles, with the advantage of continuous cutting, and modifications to suit table and tool feeds. Edge, and face mills are used, and gangs of cutters largely, with solid, or inserted teeth. Very wide cutters can be employed, up to a couple of feet or more.

As in planing machines, housings are both fixed, or one is made capable of extension, or removable, and some machines are open-sided. One, two, three, or four cutter spindles are used on cross-rail, and on housings. Feeds can be changed for roughing and finishing cuts. Driving is by belt or by motor.

Fig. 101, Plate VIII., illustrates a large plano-milling machine with four spindles, two vertical ones on the cross-rail, and one on each upright. Five sides of an object can thus be milled, including top, two sides, and two ends. In order to effect the latter operation, the saddles carrying the vertical spindles have a power feed across the rail, in which case the table remains stationary; when milling longitudinally the table is fed towards the cutters. If the work is short, and the table comparatively long, a piece of work may be set while the other is being tooled.

In the machine shown, the table is fed by a large screw set centrally, and driven from cone pulleys at the back. The cross-rail is raised and lowered by a vertical screw in each housing, and the saddles for the horizontal spindle have also separate raising screws. Each slide carrying its spindle is moved to or fro to vary the depth of cut by screws. If necessary, a single long mandrel can be supported between the two horizontal spindles to tool across broad areas. Each spindle is driven through gearing, the two vertical ones from the horizontal splined shaft lying above the rail, and driving through bevel gears from a vertical shaft to the left. The horizontal spindles derive their motion from bevel and spur gears, driven off the same vertical shaft.

A machine with a single horizontal spindle is shown in Fig. 102, Plate VIII., designed for general work, such as locomotive rods, levers, links, &c., and castings of various kinds. The table, having a travel of 6 ft., and accommodating pieces up to 3 ft. in width, slides on square gibbed ways, being moved by a central screw, driven from a cone pulley and gearing at the back, affording several rates of feed. Rapid hand and power motions are also provided for adjusting purposes. The uprights are bolted to the sides of the bed, and tied together at the top with a distance piece. Upon the faces of the uprights the cross-rail is adjustable by means of two vertical screws, rotated simultaneously by bevel gears and a cross handle at the top; the weight of the rail is counterbalanced by chains and weights. There are two saddles on the cross-rail, moved across it to any desired position by screws and a handle; the left-hand saddle carries a fixed bearing for the cutter spindle, and an adjustable stay bearing for the arbor, so that two cutters may be used, as shown, with a support between them. The right-hand saddle is fitted with a similar stay to receive the outer end of the arbor. Flexible tubes conveying lubricant from a pump are brought down to the cutters.

The cutter spindle also runs in a fixed bearing on the left-hand end of the rail, and it is driven from a cone pulley at the back, up through mitre gears to the spindle gears, which are spurs; six different speeds are available. A vertical spindle attachment, which is seen lying on the ground, can be clamped to the cross-saddle, for doing edge milling. It has a tapered shank to fit the hole in the spindle nose, thus changing the direction of motion to right angles for the vertical cutter spindle.

The employment of the plano-millers has increased very much of late years. The earlier developments arose in the United States, but numerous machines are built in England and Germany. The term "plano" relates to their close affinity in design to the planing machines,

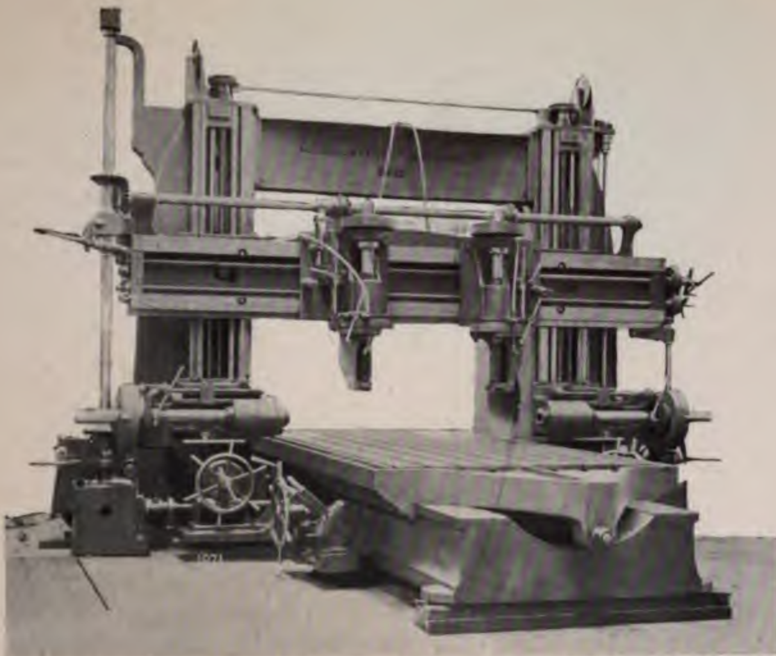


Fig. 101.—Four-Spindle Plano-Milling Machine. (Kendall & Gent, Ltd.)

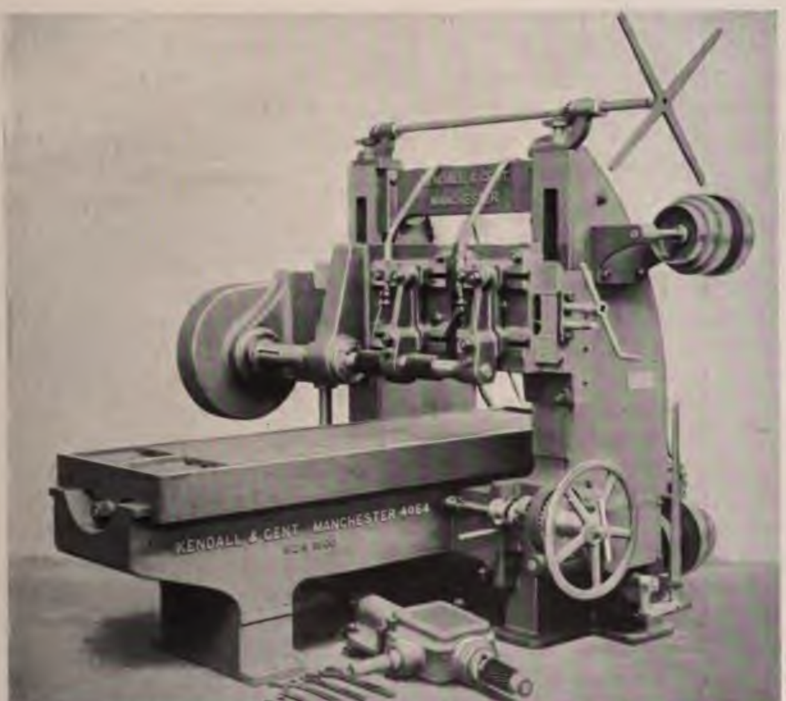


Fig. 102.—Single-Spindle Plano-Milling Machine. (Kendall & Gent, Ltd.)

To face page 94.

he term "slabbing" to their capacity for cutting on broad plane surfaces. They become rivals to the planers in this class rk, but have not ousted the latter. Though spheres of operation overlap very much, ich has a well-defined field of usefulness.

e special value of the plano-miller lies in ict that it is able to operate over a broad at once. It may or may not reduce such more rapidly than the single-edged tool planer which will take much deeper cuts. depends on many conditions; as the build e machine, the kind of cutter used, its form, its breadth, lubrication, &c. But d modern machine may be considered as mical as the planer even in tooling broad surfaces with roughing cuts, though not table when a very accurate finished surface uired. But when surfaces are not plane, uilt-up gang cutters operated in a plano- leave the planer far behind, in rapidity ion and in uniformity of results in a large er of pieces. Moreover, the machine is ably adapted for profile work when a al spindle is included, the spindle slide controlled laterally by a form or pattern article to be profiled held on the table.

principal developments of these machines taken place in their increased stiffness to e the cutters to do heavier work with less tion, in the multiplication of spindles, and provision of a larger range of speeds and for roughing and finishing, on different s and alloys.

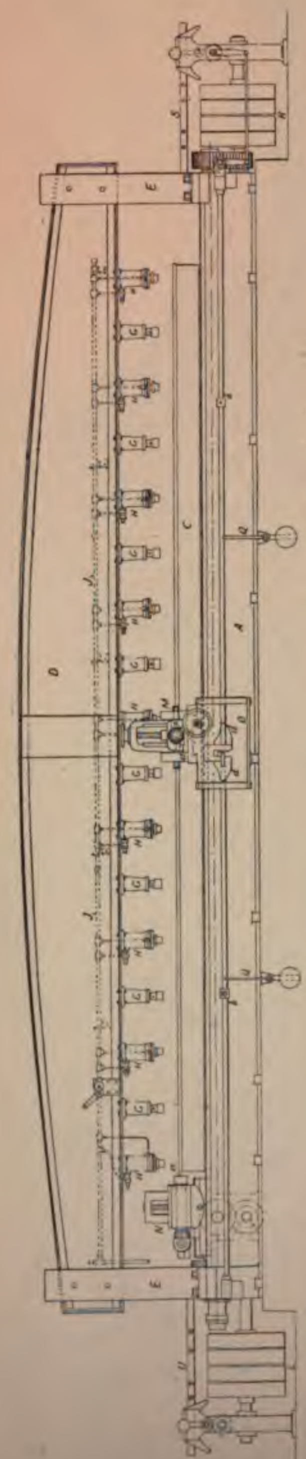
ated Girders.—Those in which the web ntinuous, instead of being formed by members. Plated girders are of single, double box section. It is usual to assume he horizontal flanges sustain the horizontal es, and the web the vertical. Vertical ers are necessary to reinforce the web able it to resist crumpling and crushing es. The objection to this form is weight, vaste of material, so that it is less used formerly except in comparatively shallow . The objection to box girders is the lty in painting their interiors, for which holes must be provided.

te girders are built up by means of angles d to the webs and flanges. When girders exceed in length that of the standard plates rolled, they are united by joints; the webs and flanges break joint, and are connected up with broad covering plates riveted through the web and flanges. Tee stiffeners may be riveted down the web covering plates. Lengths of angle also form connections at the joints. When girders are built up in the shop the rivets are omitted from all the holes in covers, angles, web, and flanges on one side of each joint, and a few tacking bolts inserted. The girders are then separated at the joints for transit, and the riveting completed at their destination.

Plate Dowels.—Metal dowels having the pin and the hole in broad plates which are sunk flush, and screwed into the joint faces of the patterns. They are more secure than wooden dowels, or than the peg and cup form, and are used therefore for the larger and heavier class of patterns.

Plate Edge Planing Machine.—A special type of planer designed for planing the edges of plates for bridge, girder, and boiler work. In all machines of this kind, the work is bolted to a table over which the tool box travels. The length of cut ranges from 8 ft. to 40 ft. in the smallest and largest machines made. Many machines combine provision for planing an edge and an end. The general design includes the bed and table on which the work is clamped down by means of hand screws, or hydraulic rams, so leaving the edges unobstructed for tooling. The screws or rams have their bearings in a stiff beam above, carried between end standards. The beam in the largest machines is built up of steel plate, in the smaller of cast iron. The tool carriage traverses along a face of the bed, the attendant standing on a platform attached to it. The tool usually cuts on both strokes, the tool box being reversed automatically at the end of each cut. In some machines the reversal is avoided by having two tools.

A modern machine is shown in Fig. 103, by Francis Berry & Sons. It has two beds, A, B, at right angles; C, C are tables on which the plates are carried; D, D are cramping beams or girders, the function of which is to hold the plates securely on the tables C. The beams are



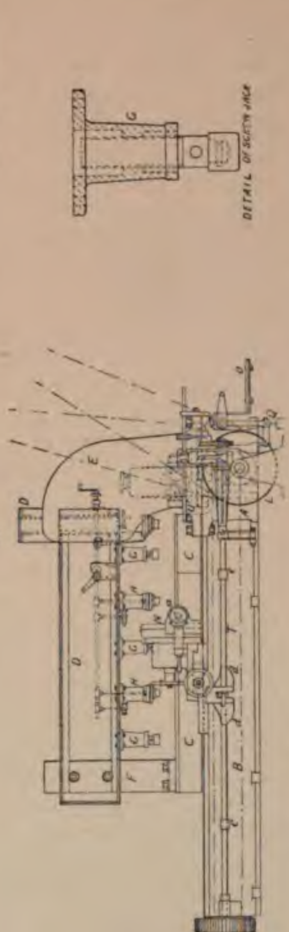


Fig. 103.—Plate Edge Planing Machine. (Francis Berry & Sons.)

supported in standards E, E, F, a feature of which is that the beams overhang the table, so permitting of the insertion of plates of any length, the ends of which may pass along in front of the standards. In many of the smaller machines, hand screws alone are used for clamping the plates down by. In this, provision is made by screw jacks G, and also by hydraulic rams H. The supply pipe for the latter is seen at J. The fast and loose pulleys for driving and reversing are shown at R for the longitudinal traverse, and at L for the end cutting, the latter driving through bevel gears. The driving is through a large screw in a trough, one in each bed. The ends of the screws are fitted with ball thrust bearings, with adjustment for wear, and gun-metal nuts drive the tool boxes. As these cut on both strokes the screws run at the same speed in both directions. The tool boxes are shown at M and N. M has a travelling platform O for the attendant to stand on. The tool in the axis *a* of the box is turned round for the double cutting. The reversals of the box are derived from the long rod supported on tumblers Q, and having adjustable dogs *b*, and moving the belts on the pulleys R through the forks S for the long traverse. The rod T, with dogs *c*, *c* actuates the belt forks U for the cross traverse; *d*, *d* are the horns or cams on the tool boxes which strike the dogs.

Until recently the method of driving has been by belt from shop shafting. Latterly the electric motor has been fitted to some machines, the belt pulleys remaining as before. In this case the motor is mounted on top of one of the end standards of the machine, and drives down to the pulleys by open and crossed belts, the motor shaft having a wide pulley to take the two belts.

Plate Flattening Machine.—*See* **Flattening Rolls.**

Plate Furnace.—An ordinary reverberatory furnace used for heating plates in the boiler and plating shop, which have to be bent or flanged.

Plate Mill.—A reve
prising two pairs of ro
line, one pair for r
finishing. The plat

pair, and is then carried along to the other pair on a travelling table. The roughing rolls are *grain* rolls, the finishing rolls are *chilled*. The top roughing roll is counterbalanced, the top finishing roll runs freely, and is revolved only by the friction of the plate. The top rolls are slightly larger than the bottom rolls

Fig. 104.—Plate Moulding.

in order to extend the upper surface of the plate more than the lower one, and so curve the plate downwards slightly, and prevent collaring around the top roll. As the plate extends almost wholly in the direction of its length, at a certain stage when the width has been obtained, the plate is turned at right angles in the roughing rolls to impart the length. When the correct thickness is nearly reached, the plate is passed through the finishing rolls.

To change the plate from the roughing to the finishing rolls *live rollers* are carried in a travelling or traversing table which is moved along by means of worm or bevel gearing, actuating the axles of the travelling wheels.

The rolls expand by continual contact with the heated metal, the central portions becoming larger than the ends. Hence rolls are turned smaller in diameter there by about $\frac{1}{32}$ in. to allow for the expansion which takes place. If this were not done, the plates rolled would be buckled about the centre. For the first few days after putting in new rolls, narrow plates are rolled until the central portions of the rolls expand, after which plates of full width are ro[illegible] spring, so that wide plates [illegible] e middle than at [illegible]

ing patterns, or pattern parts on plates, the faces of which are used to ram the joint faces of the moulds against. It is an extension of the bottom, or joint board method, on which a pattern is simply laid to be rammed. But the plate and its pattern are united, either being fastened, or cast together.

The simplest plate is made of wood, a **Bottom Board** in fact, but having its pattern or patterns permanently attached. The plate of wood is made by any of the methods adopted in preparing bottom boards to ensure permanence of form; as open joints, crossing strips, and of battens, when conditions permit of their use. Pattern parts may be moulded on one side of two distinct plates, or on opposite sides of a wooden plate, as say a column or pipe pattern in halves, Fig. 104. In the first case, the pattern has to be moulded by turning over, first one-half being rammed, and then the other half in a pair of boxes, by one man, or one set of men. In the second, each portion of the pattern on its separate plate is rammed without turning over, the box parts only coming together for closing the mould,

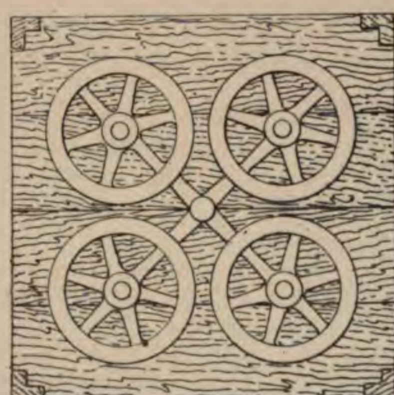


Fig. 105.—Plate Moulding.

and they may be rammed by two men, or sets of men. The economies of this division of labour are worth making. Fig. 105 shows hand-wheels on a wooden plate, with corner pieces for locating the boxes.

Wooden plates are suitable for a large

quantity of work, and they have been and are used to a great extent. They not only save the moulders' time in making a joint with the trowel for every mould, but they help to preserve the pattern true, and from injury. In fact in the case of many long, slight, and flimsy patterns this is the most important economy

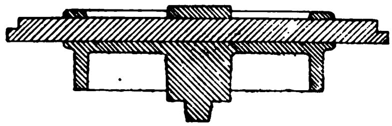


Fig. 106.—Trolley Wheel on Plate.

of the plate, for without it, the trouble of ramming up truly, and preserving edges would be excessive.

Although timber is not very durable, yet a carefully made plate will endure hundreds of mouldings before it requires renewal, and this is more than ample for most patterns in average shops. An objection to it is, that many patterns require joints in more than one plane, up and down, or curved, and sloped in various ways,

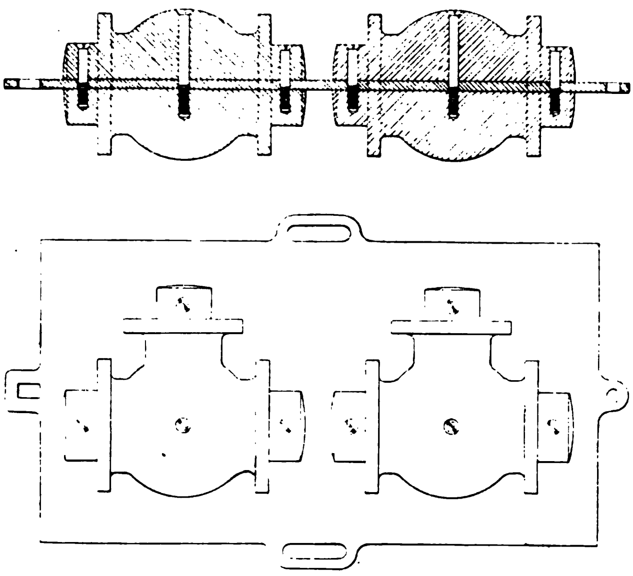
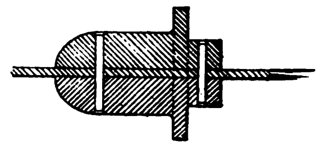


Fig. 107.—Pattern Parts Screwed through Plate.

and these cannot be readily cut and formed in wood without causing weakening of the plate, and difficulties in matching the joints in top and bottom. Something is done in this way. But it is better in high-class work to abandon timber for metal. Thin plates can be used, say from $\frac{1}{4}$ in. or $\frac{3}{8}$ in. to $\frac{3}{4}$ in. thick, according to area; and joints, however intricate, can be made by casting, with the certainty that the top and bottom will match.



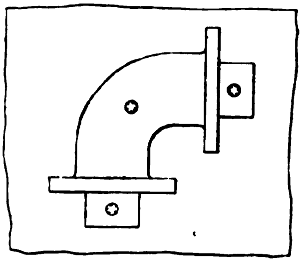


Fig. 108.—Pattern Parts Riveted through Plate.

But the practice of casting pattern parts with their plates is not adopted to so great an extent perhaps as that of attaching them to plain plates, the former being reserved chiefly for work in which the joints are irregular. When they are plain, it is usually better, special cases apart, to make plain plates, Figs. 106-109, having their faces planed, milled, or ground, and attach the pattern work separately tooled, and got up, to them with screws, or with rivets. This saves a lot of filing and scraping, generally necessary when patterns and plates are cast together.

The difficulty of ensuring perfect coincidence between the edges of patterns and moulds in top and bottom is well known. This is the chief difficulty in plating patterns. When patterns are on one side of the plate only, leaving a plain top, the trouble of matching is not present. When the halves or parts occur on opposite sides, the pattern halves or parts are prepared first, independently of the plate. Holes are drilled through from one to the other, and fitted with pins, or screws, Fig. 107, or rivets, Fig. 108, and the patterns got up while thus secured. They are then separated, and holes drilled through the plate to correspond, and the pins, screws, or rivets secured through pattern parts and plate. In this way the perfect coincidence of top and bottom is ensured.

When separate pattern plates are used, the two plates can be fitted together, with the patterns on opposite sides. Or they may be set by centre lines scribed over from one plate to the other. If there is any difficulty in getting edges to match, the patterns can be soft soldered to the plates in the first place, a mould taken, and corrections made if found necessary, and finally the pattern parts be attached permanently with screws or rivets.

In many cases the fitting of pattern parts is more simple. Thus, a pattern may occupy one side only of a plate, but have a print, or print and boss on the lower side. Then a hole can be drilled, and the print, solid with the pattern, be thrust through. The print, or boss, Fig. 109, must, of course, be longer than the actual print or boss required, by the thickness of the plate. Runners are almost invariably fitted to pattern plates. They are either pinned or screwed on, or cast with their plates, Fig. 110.

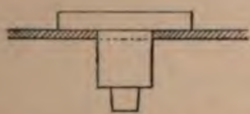


Fig. 109.—Gland fitting through Plate.

The plates are of wrought, or cast iron, the first being lighter because they can be used of $\frac{1}{4}$ in. or $\frac{3}{8}$ in. thickness. But cast iron is generally preferred as being more rigid to ram on. Lugs are required with holes to fit the pins of the boxes. One hole fits its pin closely, the other, or others should only fit the pin in one direction, Fig. 110. Slots are frequently cast for the hands as shown.

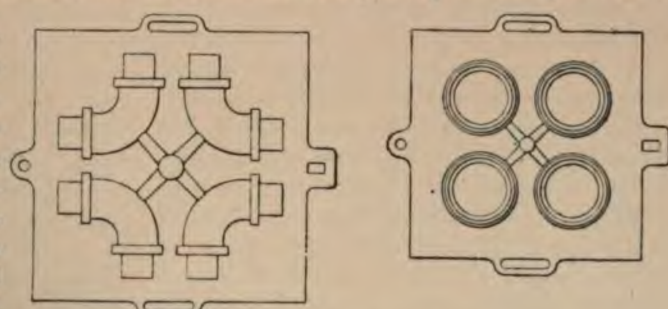


Fig. 110.—Plate Moulding.

When patterns are cast with their plates, mould parts are first rammed as though for casting from. They may be prepared by turning over, or from odd sides. They are mended and cleaned carefully, and then the mould parts are separated by a frame, laid outside, and the thickness of which corresponds with the thickness of the plat[illegible] [illegible]uld-ing frame is [illegible] Then the pattern frame is removed, leaving a mould comprising top and bottom pattern parts, and a mould for the plate.

Plate Rolls.—Wide rolls for bending or flattening plates. *See* **Bending Rolls, Flattening Rolls.**

Plates.—The largest masses rolled in iron and steel, and which range in thickness from above $\frac{1}{4}$ in. up to about 2 in. They are rolled to much larger dimensions in steel than in iron. Piling is necessary for iron, but ingots are used for steel, which is the reason why the latter can be rolled larger and much more cheaply. The basis of limits is the *area*. The area divided by the length gives the width of a plate that can be rolled in any given thickness, and the area divided by the width gives the length. In steel, the real limit to width is from 10 ft. to 13 ft., which are the greatest widths that the railway companies can carry. Plates 30 ft. long by $3\frac{1}{2}$ ft. wide are used in shipyards, and the standard plates for Lancashire boilers are now 22 ft. long, by $4\frac{1}{2}$ or 5 ft. wide, so that the rings are made of single plates, with avoidance of two of the three longitudinal seams required when a belt took three iron plates. A Snedshill iron plate, $\frac{3}{4}$ in. thick, was of 80 superficial feet area; a $\frac{3}{4}$-in. steel plate can be rolled of 250 ft. area. The extras are also small, due to differences in manufacture. The size of a pile is severely limited, that of an ingot is so great that it pays to roll large plates from massive ingots, and cut them up into smaller plates. With piled plates, the losses consequent on shearing the edges are greater than on steel [illegible]labs.

[illegible]tes are rolled directly from the ingot, or

they are cogged first in a slabbing mill, put into a reheating furnace, and then rolled finally. A modern mill is capable of turning out from 1,000 to 1,500 tons per week. Plates increase in thickness by sixteenths of an inch; sometimes by twentieths, as in the case of ship plates. Limitations in weight are specified, and some firms order plates by weight per square foot.

Plate Shears.—Wide **Shearing Machines**, for trimming the edges of plates.

Plate Straightening Machine. — *See* **Flattening Rolls.**

Platform Crane. — A term sometimes applied to the independent type of **Whip Crane.**

Platform Scale.—A weighing machine which is self-contained, having the arm pillar bolted to the end of the weighing platform.

Plating.—Strictly the working on plates and bars used for bridge and girder work, and the plater is the man whose duties are thus restricted. But it also includes in practice the work of the angle-iron smiths, the riveters, and the machine hands. The materials used are steel and iron. The work involves marking out, templeting, cutting, straightening, bending, flanging, welding, punching, drilling, riveting. But each of these operations is now carried on by distinct sets of men, though many platers, especially among the older hands, are capable of undertaking either class of work.

Marking out.—This, in most shops, and invariably in the largest, is the work of a man or men, who, like the liners-out in the machine shop, do no other work. Work is marked out on the floor or on drawing boards, on the surface of the actual plates, or bars to be cut, or on templets. It is done to actual working size, and involves a knowledge of the simpler geometrical problems, and the methods of development of the envelopes of solids from plane figures. A knowledge of the rules of mensuration is also necessary. The surfaces of drawing boards are painted black, and lines are marked with chalk, the chalk line being used for straight lines. Or the surfaces are whitened with chalk, and black lines are drawn in pencil, or with scriber, compass, and trammels. Plates are whitened with chalk, or preferably with a thin solution of common whiting in water dried off. Pointed instruments as scribers and compasses are preferably used on plates.

Templeting.—When work is repetitive, due to certain jobs often recurring, or to the similar members in an individual job being numerous, templets are made. These are of wood, or steel sheet. Wood is lighter to handle, and is cheap, but loses its accuracy. It is suitable if used in narrow strips, and large frames are made with narrow strips halved at the corners to give overall sizes of plates, or the locations of rivet holes. Lengthwise no shrinkage takes place. Straight grained yellow pine is the most suitable material. For long service steel sheet is preferred, as being permanent in shape, and dimensions, and standing the rough usage of the shop. In large templets this is framed up in strips and welded or riveted at the corners. Sometimes a first structure is first built up, and the various members are used as templets to mark off all other structures of the same kind.

Cutting.—Plates are ordered from the iron and steel works to definite dimensions which leave allowances for planing the edges. The **Plate Edge Planing Machine** is used for straight edges. The lathes, horizontal, or vertical, for circular plates. Holes are cut by punching out the centre, and chipping, or in machines for **Oval Hole Cutting.** Shearing is practised when a large amount of material has to be removed from an edge, but this is always followed by planing in the best work. Bars, angles, tees, channels, and all sections are severed and trimmed in a **Cold Sawing Machine.**

Straightening, or Levelling.—Plates are levelled by the hammer on the **Levelling Block**, or in **Flattening Rolls.** A good deal is done by hand, for which skill is requisite. It is open to objection on account of the bruises, and the injury done to the plate. The art of straightening consists in extending the metal by hammering around depressed portions. In the flattening rolls the extension is more general, operating over the whole area. All levelling is done cold.

Bending.—Plates are bent cold, and hot; cold to large curves, hot to the smaller radii only. The work of the **Bending Rolls** is so gradual that thick plates can be readily bent

cold, but small cylinders, such as cross tubes and uptakes, must be heated. Envelopes of spherical objects must be heated, whether done by hand or in hydraulic presses. Any sharp bendings, such as the setting out of fire-boxes around the firing holes, must be done hot. Sectional forms, as angles, tees, channels, are bent hot. *See* **Angle Iron Work**. This is done by hand against suitable bending blocks, or in machines containing suitable rolls.

Flanging.—This operation is performed laboriously by hand work in short heats of a few inches at a time, or between dies under

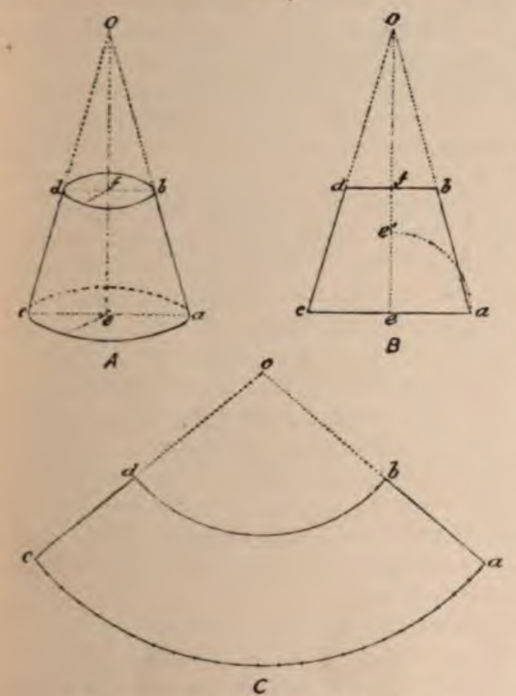


Fig. 111.—Envelope of Conic Frustum.*

hydraulic pressure. *See* **Flanging**. This operation has, since the introduction of mild steel, taken the place of union by means of angle irons. Akin to flanging is the setting down of tees and angles by joggling, to avoid the use of packing strips.

Welding.—This is relegated chiefly to the angle-iron smith, who also welds other rolled sections, furnace flues, and cross tubes for boilers. The two last are mostly done now by the aid of power hammers, and glut welds are preferred to lap welded seams. Plates are seldom united by welding in other than circular forms, riveting being preferred. Bars and rods are welded to their eyes for tension rods.

Punching.—The relative value of this operation has lessened with the growth of mild steel, and of improved methods of drilling. Plates and angles for the best work are seldom punched now, and when they are, reamering is insisted on, and drifting forbidden. Multiple punching is not of so much value as formerly, because multiple drilling machines are more common. Punching by portable machines in sections of work in large progress is frequent, but reamering follows then, in strict specifications.

Drilling.—This is of great importance in a modern shop, but the work is seldom done by the platers, but by drillers who do nothing else. A large number of machines have been designed to suit bridge and girder work, some fixed, many portable. Large numbers of wall machines are used to operate independently on different jobs, or on a single long plate, bar, or section. The stringency of specifications relating to drilling and reamering has favoured the growth of portable pneumatic machines, so that parts of work can be fitted in place, and drilled and riveted *in situ*. In repetitive work the multiple spindle machines, having provision for adjustment of centres, are used.

Riveting.—Machine riveting has to a large extent displaced hand riveting, with great reduction in labour costs. The hydraulic system is mostly used for fixed shop machines, but the pneumatic divides favour for the portable machines. Caulking and chipping are done by the same agency.

Development—Cones.—Envelopes of conical figures occur with frequency in the work of the boiler-maker, coppersmith, and tinsmith. They are among the simplest bodies to be marked out. The envelope of a cone, Fig. 111 (A), is a sector of a circle, the radius of which equals the slant height, *a-o*, of the cone, and the length of arc of which equals the circumference of the base, *a c*. The envelope of the frustum of a cone has the dimension just named for the base, and for the top the similar dimension at the plane of truncation, *b-d*.

But in marking out sheets, the circumference

is not reckoned as diameter × 3·14159, because of the difficulty of measuring round an arc of a circle, but instead the method of stepping round with compasses is adopted.

An example of a frustum will serve also for a complete cone. In the right cone, Fig. 111 (B), it is required to obtain the envelope of the frustum of perpendicular height, *e-f*. Strike a quadrant *a-e′* of the radius of the base of the cone *e-a*, and divide it into any convenient number of equal parts. Strike an arc,

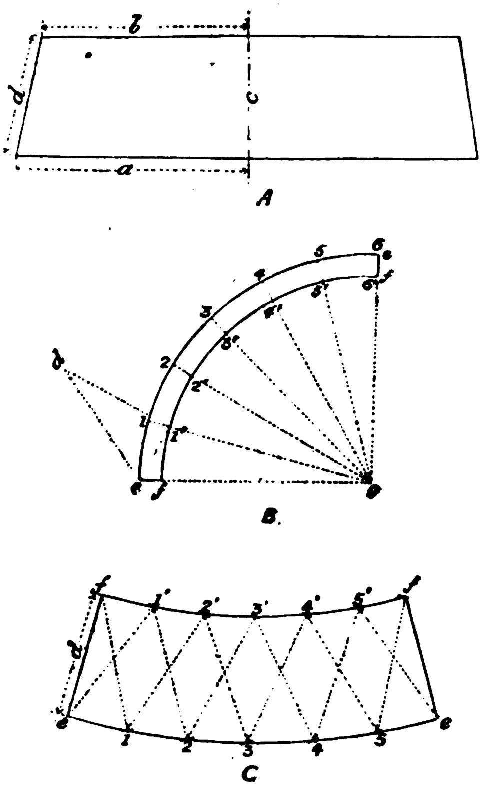


Fig. 112.—Envelope of Conic Frustum.

Fig. 111 (C), *a-c*, with radius *o-a* equal in length to the slant height of the cone, and divide off a length equal to four quadrants by using the compasses as just set for a given number of equal divisions. Draw the line *c-o*, and strike the arc *b-d* with radius *o-b*. Then the segment *acdb* will be the envelope of the frustum of slant height *a-b*.

But there are cases in which the conical form departs slightly from the cylindrical shape, making the apex so distant that it is impracticable to work from it. Then the method of triangulation is employed, shown in Fig. 112.

In this figure (A), *a* is the larger radius, *b* the smaller, *c* the perpendicular height, and *d* the slant height. Draw the arcs *e-e*, *f-f*, Fig. 112 (B), to the radii *a* and *b*, and divide *e-e* into any convenient number of equal parts, 1, 2, 3, &c., and prolong the divisions to the centre *o* to intersect *f-f*. These divisions, as we saw in the previous example, are for the circumference of the base and top, and the question of slant does not affect them. By the triangulations the length of slant face is to be obtained thus: Erect a line *e-d* perpendicular to *e*-1′, and set off on it the length *e-d* equal to the perpendicular *c* in Fig. 112 (A). Join *e-d*, and the length *e-d* will be the length of the slant height *d* in Fig. 112 (A).

To obtain the enveloping plate, Fig. 112 (C), draw a line *e-f* of the same length *d* as the slant height *d* in Fig. 112 (A). From *e*, *f* strike arcs *e*-1, and *e*-1′, with radii corresponding with those similarly lettered in Fig. 112 (B). With the length *e-d* as radius strike arcs from *e*, *f* intersecting those first drawn. Repeating the radii and starting from 1, 1′ as centres find successive points of intersection 2, 2′, and so on until the length of the envelope is completed. Then curves drawn through these intersections will, with the end lines complete the envelope. Allowances for joints or seams must be added.

Plates for conical fire-boxes are also marked out as in Fig. 113. Set out the lengths *a-b* and *c-d* equal to the circumference of the box at top and bottom without the riveted seam, and at the distance *e*, *f* apart, equal to the slant height of the box. Draw lines *a-c*, *b-d*, and raise perpendiculars from each, meeting at *g*. Set off a point *h* nearer to *f* than *g* in the proportion of 4 to 5 and draw the curve *a-h-b* with a lath. Draw the curve *c* to *d* parallel with it, completing the outline of the plate.

Curves of Large Radius.—These occur in boiler work, in pattern-making, and in laying out templets of various kinds for bending, or cutting by. As the location of a centre for striking such curves is impracticable, other

methods are adopted. The usual device is shown in Fig. 114.

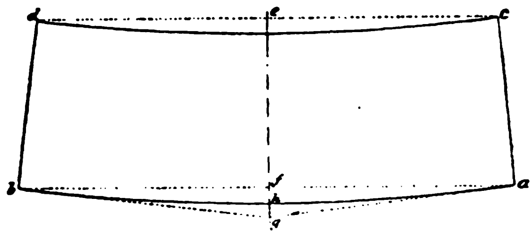


Fig. 113.

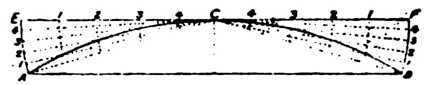


Fig. 114.

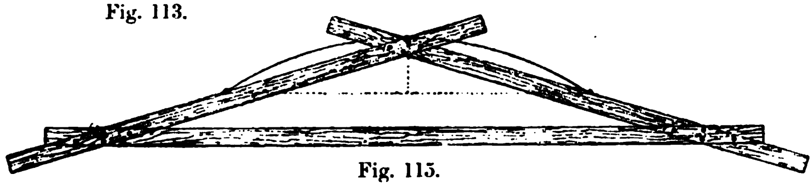


Fig. 115.

Curves of Large Radius.

Let ABC be three points in the curve. The height of the versed sine C of the chord may be already known, or it may be obtained from the length of chord, thus:—

$$\text{Versed sine} = R - \sqrt{R^2 - C^2},$$

where R is the radius, and C half the chord.

Draw a line parallel with AB, and passing through C. Connect AC, BC. From C as centre with radius CA, CB draw the arcs AE, BF. Divide AE, BF into any convenient number of equal parts, 1, 2, 3, 4, &c., and draw lines from these to C. Divide CE, CF into the same number of equal parts as AE, BF, and the intersections of these two sets of lines will give points in the curve required.

Another way is to screw three straightedges together, Fig. 115, and slide them against pins fixed at the extremities of the chord, and then with a tracer pin set in the apex *a* of the triangle, mark the curve. The tracer pin must be the third point C of Fig. 113, equal to the height of the versed sine.

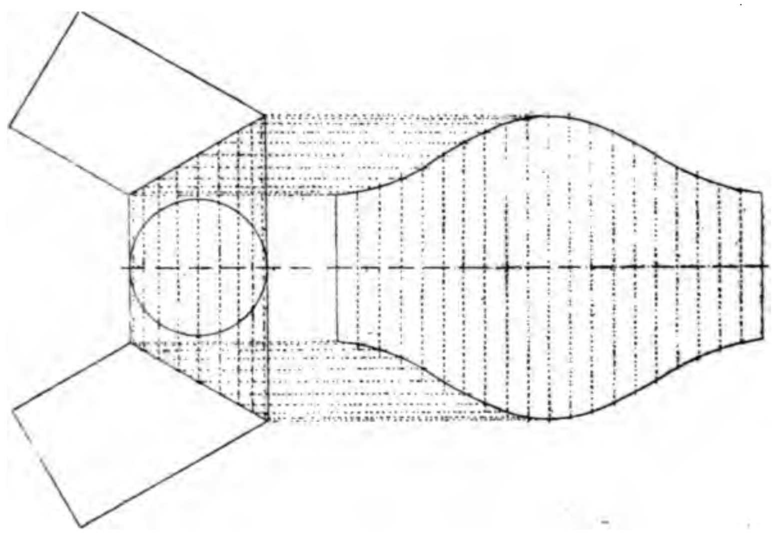


Fig. 116.—Cylinders Meeting at an Angle.

Many large curves are regularly struck in the work of the various shops by bending laths or strips of wood, preferably of square section, guided by points located at intervals, and marking along the edge of the lath with a scriber point. In wood-work the lath may bear against nails driven in, and standing up a half inch or inch. On metal sheets the lath must be held by the hands, or clamped down

when practicable, or laid against weights. A stiff lath that can just be bent conveniently to a radius will give more accurate results than a flimsy one that will show kinks and irregular curvatures.

Cylindrical Bodies.—These occur constantly, being fitted at various angles and to flat or curved surfaces and against other cylindrical bodies. The principle of development is simple, and is illustrated by Figs. 116-118. Essentially it consists in drawing the enveloping sheet as though unrolled. The circumference is divided into any number of equal parts, and on each part a length is measured corresponding with the length taken on the corresponding line of equal divisions marked on the plan of the article. The diagrams illustrate constructions which are self-explanatory, and typical of many others which occur in practice.

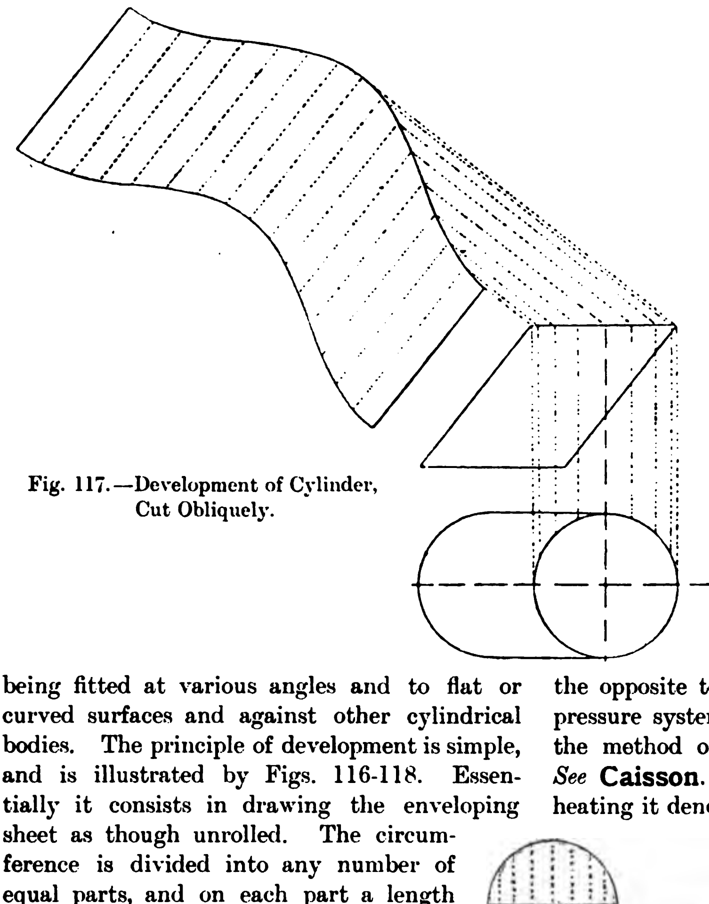


Fig. 117.—Development of Cylinder, Cut Obliquely.

Platinum (Pt; 193·3; sp. gr., 21·5; sp. heat, ·033 to ·038; melting point, 3,080° to 3,500° Fahr.; coefficiency of expansion by heat, ·000005; weight in lb. per cubic foot, 1,344 lb.; per cubic inch, ·755 lb.)

Platinum is one of the rare metals and occurs always native, but alloyed with other metals such as palladium, rhodium, osmium, and ruthenium. It is malleable and ductile, possesses a bright white colour, is very infusible (hence used for crucibles and evaporating basins), and is unaffected by acids or oxygen. When finely divided, platinum possesses the property of condensing gases on its surface; the consequent raising of temperature thus makes the metal valuable in the self-lighting mechanism for incandescent gas mantles. Its coefficient of expansion being nearly equal to that of glass, platinum wires may be sealed into glass, as in electric glow lamps, without fracture when cooling. Platinum is also used in the touch-holes of small arms and cannon, owing to its power of resisting corrosion, also in electrical work for contacts. Commercial platinum is alloyed with iridium to increase its hardness.

Plenum Processes, from Lat. *Plenus*, full.—Denotes the opposite to vacuum, and relates to certain pressure systems. In caisson work it signifies the method of excavating in compressed air. *See* **Caisson.** In systems of ventilation and heating it denotes pressure systems as opposed to those in which exhausting or vacuum fans are employed. *See* **Ventilation.**

Fig. 118.—Cylinder Fitting a Larger Cylinder out of Centre.

Pliers.—Pincer-like tools, having jaws shaped specially for gripping, or for cutting. Ordinary pliers have flat-faced jaws adapted for holding

almost any kind of strip, or wire, and cutting jaws are included at one side. For working on fine pieces, or in confined. spaces, flat or round-nosed pliers are employed; they are tapered off thin and narrow, but are of course not so powerful as the ordinary tools. For holding gas tubes and rough rods, gas pliers are used, with concave recesses in the jaws, formed with serrations which grip the work firmly and prevent it from turning. A screw-driver blade is often formed on the end of one handle to serve for emergency use. Pliers used only for cutting are sometimes constructed with the jaws at the ends of the nose, and detachable for the purpose of sharpening or replacement in case of fracture. Belt pliers, used for perforating holes in the ends of belts, have a punch and a bolster by means of which holes can be rapidly made.

Plinth.—The square member which forms the lower division of the base of a column. *See* illustration of Tuscan Column under **Architecture**, Vol. I., p. 175.

The projecting face at the foot of a wall just above ground is also called a plinth.

Plotting.—Laying down certain lines and curves on squared paper, to show in a graphic manner any of the problems that arise in engineering. The vertical and horizontal lines, ordinates, and abscissæ respectively may stand for anything required; loads, pressures, tensions, measures, times, &c., and the lines drawn through these show at a glance the result of the correlation of two sets of figures.

Plough.—A plane used by joiners for ploughing the grooves for panels and tongues. It is one of his most expensive tools, its cost ranging from about 12s. to £2. The width of the groove it planes is fixed by the width of the cutting iron used, and therefore ploughs are provided with a set of irons of different widths. The plane has an adjustable fence which is set at the same distance from the iron as the groove is required from the edge of the wood. The depth of the groove is fixed by a stop, which is raised and lowered by a thumbscrew on top of the plane. A metal plate, less in thickness than the width of the narrowest iron, bears on the bottom of the groove and regulates the thickness of the shavings. The iron is wedged in the ordinary way, but its upper end is hooked so that it can be knocked back with a hammer. The fence is adjusted either with wedges or screws.

Plough—Agriculture.—In agriculture this is an implement for cutting up, turning over, and loosening the soil, preparatory to sowing seed. Ploughs are usually drawn either by animal power, or by wire ropes winding on drums mounted on self-moving engines. The ground is ploughed into a series of furrows by starting at one corner of the field and ploughing along one side and then back in the opposite direction. The furrow is cut by the share, and the earth is turned over by the twisted breast or mould board which forms a continuation of the share. In its simplest form a plough has no wheels, the work done being controlled by the man at the handles. This is called a swing plough. When steel ploughs were introduced they were mounted on wheels, the small one travelling on the land, and the larger one running in the furrow; the former regulated the depth of the furrow. For most purposes these are a considerable improvement over the old-fashioned swing plough. A plough may be either single or multiple, that is, it may have a single share to cut one furrow at a time, or it may have two or more shares to cut a number of furrows simultaneously. The latter variety are used chiefly when steam power is employed for drawing them. Where steam power is employed the plough is of the balanced type carrying two separate sets of shares, one set for working in one direction, and the other set for working the opposite way, so that the body of the plough is not swung round when the end of a furrow is reached, but the shares that have reached the end of their furrows are raised into the air, and the reverse set lowered for working back. The plough is shifted laterally the width of the land ploughed at the last bout, the furrow wheel returning in the last furrow cut, serves as a guide for the steersman during the return bout. The shares, breasts, &c., are so constructed that the land is always turned over one way in whichever direction the plough may be worked. The width and depth of furrows vary considerably according to circumstances and the kind of tillage required. For cereal

crops the furrows may be from 9 in. to 15 in. wide by 6 in. to 12 in. deep, and for deep ploughing, such as in forest lands, and in sugar and vine cultivation, the furrows may be from 16 in. to 20 in. wide, and about the same depth. Shares are made self-sharpening by chilling their under surfaces, so that the soft upper part wears more quickly and leaves a thin edge corresponding with the thickness of the chill.

The best method of utilising steam power for ploughing is to station two traction engines, one at each side of the field, and haul the plough from one to the other alternately by wire rope on horizontal drums beneath the engines. The engines stand at right angles to the direction of ploughing and are moved forward by degrees to correspond with the width of land ploughed at each bout. The engines alternately haul and pay out. One engine only is sometimes used by carrying the rope round an anchor at the opposite side of the field and winding alternately in opposite directions. Ploughs are sometimes drawn by motors, but on hilly and heavy ground these cannot be depended on, and moreover it is desirable that as little weight as possible should travel over the ground.

Fig. 119, Plate IX., shows a deep single-furrow plough breaking up land previous to planting it with trees. The trailing wire rope is seen to the left, the other portion with the hauling engine being hidden by the front part of the plough. Messrs John Fowler & Co., Ltd., have developed a form of plough, Fig. 120, Plate IX., by means of which eight furrows are turned up at one bout. On reaching the end of the field the machine is swung round to reverse it, and by means of gearing the eight ploughs automatically turn over in readiness for the next traverse. In the view the hauling engine is seen, towards which the plough is travelling.

Cultivators may be employed after the land has been ploughed to further disintegrate it and allow for thorough aeration: in some cases implements such as hoes or scufflers may be worked between rows of crops for the purpose of destroying weeds and improving the soil. In the ordinary cultivator for breaking the soil, the main feature is a number of curved tines carried on a framework, supported on two or three wheels, the tines being fitted with points which vary in form. In some cases spring tines are used, which have a rather greater effect upon the soil, shaking and lifting it in a live manner which is very conducive to weed destroying.

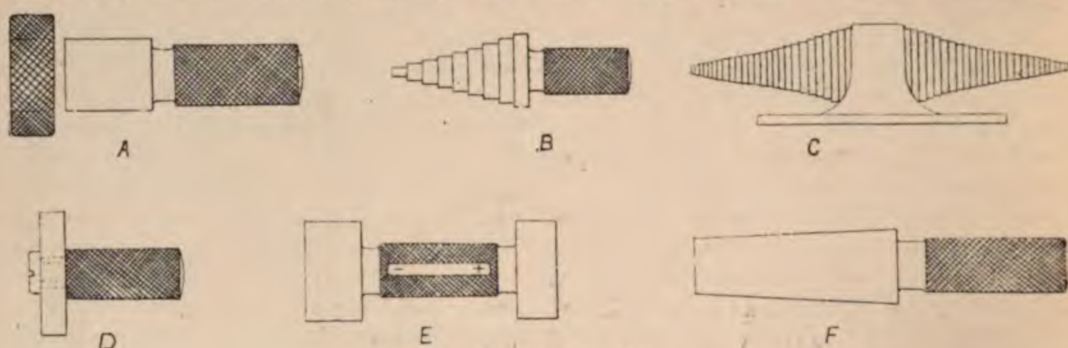


Fig. 121.—Plug and Ring Gauges.

Plug.—The movable centre in the bottom of a converter, which contains the tuyere holes. *See* **Bessemer Converter**. The centre movable part of a gas or water cock, which forms a frustum of a cone. A plug of clay, or core of sand is used for closing a flow-off gate or riser, during the time of pouring.

Plug and Ring Gauges.—The cylindrical gauges form a convenient means of testing the sizes of turned, bored, and ground work, in a more accurate manner than by ordinary calipering. They possess the advantage of completely filling the hole, or encircling the spindle, so that the roundness or otherwise is tested. The

Fig. 119.—Single-Furrow Plough.

Fig. 120.—Eight-Furrow Plough.

(John Fowler & Co., Ltd.)

Fig. 140.—Single-Cylinder Portable Engine. (Ransomes, Sims, & Jefferies, Ltd.)

relative accuracy of cylindrical gauges depends on the class of work for which they are required. The commoner kinds, for rough workshop use, are guaranteed to be accurate within about one 2,000th part of an inch, while others range from one 5,000th or 10,000th to one 50,000th. These latter are not used so much for the direct testing of work, as for reference, in setting and adjusting calipers of various kinds, so that the gauges are not subjected to appreciable wear. The ordinary pattern of gauge is that shown in Fig. 121, A; the knurling on the handle and the body affords a firm grip for the hands. The earlier practice was to leave these surfaces plain. The diameters of plug and ring gauges range from $\frac{1}{16}$ in. to 6 in., or larger in some instances. The smaller sizes up to about 2 in. are usually of steel, and above that of cast iron, but some manufacturers use steel alone.

When the gauges are used for reference only, to test other gauges, they are conveniently made of stepped form, Fig. 121, B, C, to be held in the hand, as in the first, or to stand on a bench, as in the second. Each diameter is a ring, ground and strung on a central arbor. Separate discs are also employed, to be held on handles, in the manner illustrated in D. Limit gauges, E, have the large and small diameters at opposite ends. Tapers are tested by the gauges in Fig. 121, F, made to the Morse or other standards.

Plumb.—Vertical, perpendicular, the condition assumed by a string loaded with a weight, and at rest. This constitutes the plumb-bob, which is used for locating perpendicular faces, and centres when the bob is provided with a centre point. The term plumb-line is often applied to this. A plumb-rule is a strip of wood with which the plumb-line is incorporated, and one edge of the rule is laid against vertical faces of work to test its accuracy. A plumb-level is a spirit-level which has a bubble tube at one end, by which the vertical truth of faces is checked.

Plumbago.—Also called blacklead or graphite, is one of the allotropic forms of carbon. It contains impurities, however, and sometimes these form a fairly large percentage. It occurs in Ceylon, North America, and Siberia, and at Borrowdale in Cumberland. It is also present in cast iron, and is produced commercially by heating coke in the electric furnace. It has a greyish-black metallic colour, and is greasy to the touch. Sp. gr. 2·15 to 2·35. It is a good conductor of electricity. Being very incombustible, it is mixed with clay in the manufacture of crucibles. It is also used as a lubricant, as a foundry blacking, and of course for blacklead pencils.

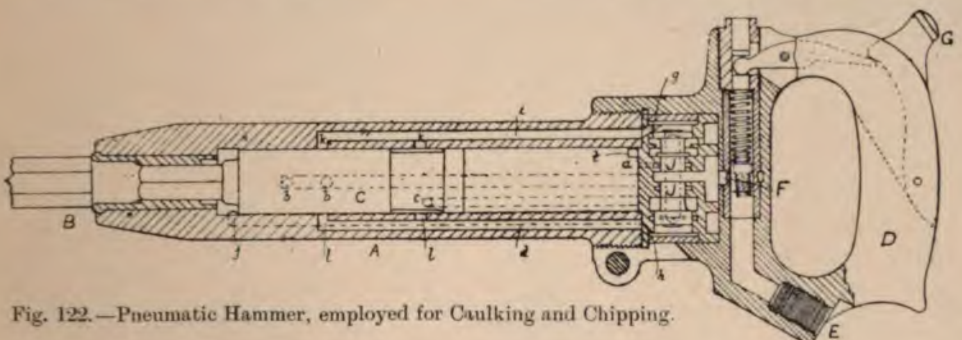


Fig. 122.—Pneumatic Hammer, employed for Caulking and Chipping.

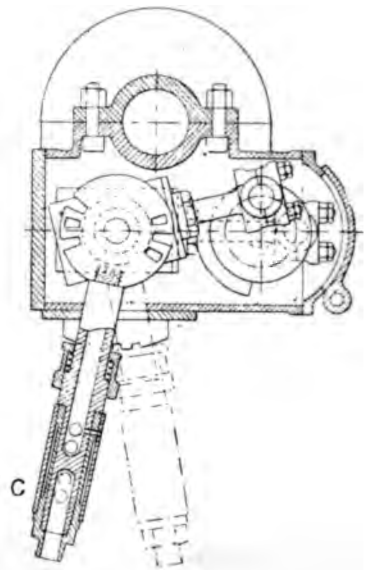
Plummer Block.—*See* **Bearings.**

Plunger.—A term frequently given to the piston, or ram of a force pump.

Ply.—A term which signifies layers, as the number of thicknesses which make up a cotton, or indiarubber, or canvas belt. Also signifies to bend.

Pneumatic Caulking Tools, Pneumatic Chisels.—The pneumatic hammer is employed to perform the functions both of caulking and of chipping, the only difference being in the form of the tools used in it. Fig. 122 is an example by the Pneumatic Engineering Appliances Co., Ltd. The cylinder A, which is comparatively short, holds the chisel shank B in a socket at the end, where it is struck

by the piston C. The air enters through the handle D, by way of the aperture E, up the passage and past the valve, when the latter is opened by pressing the thumb trigger G, through the opening F, so forcing the valves J, J outwards, letting the air through the ports *a*, *a*, and driving the piston until it strikes the chisel end, which is the stage represented in the drawing. The ports *b*, *b* are thus closed, and live air is admitted through ports and passage *c* around the recess of the piston, and into the passage *d*, and acting on the larger area of the valves J, J, forces them inwards, and the air pressure in cylinder escapes through the port *f* into the passage *g*, and through exhaust holes in the handle to the atmosphere. At the same time live air is admitted through small holes in the lower valve J, through hole *h*, along the dotted passage and by *j* into the chamber in front of C, driving it backwards; as soon as C has passed the ports



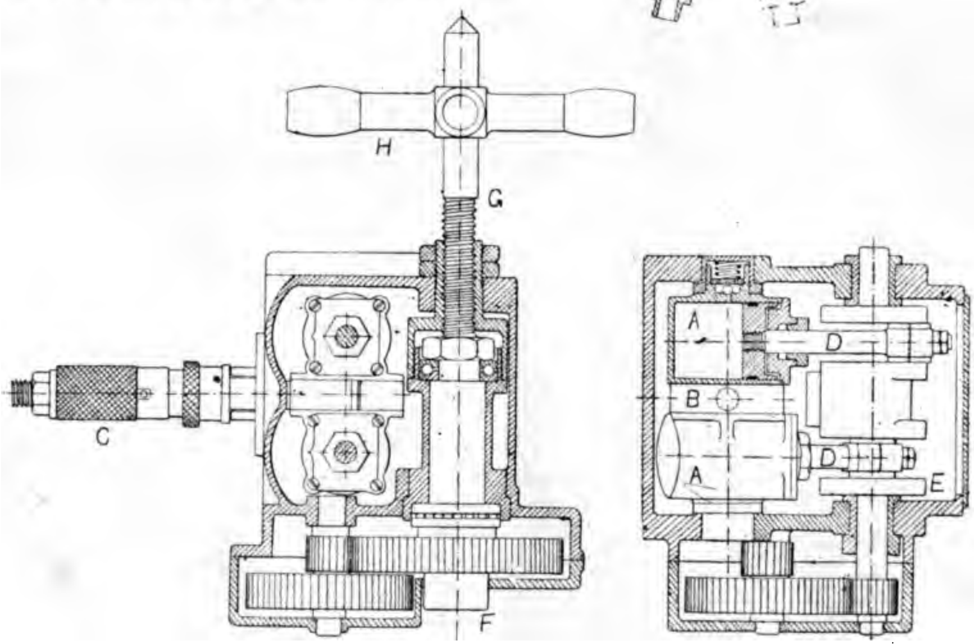


Fig. 123.—Pneumatic Drill.

b, *b*, the air pressure behind C escapes into the holes and passages *k*, *l*, and through into the handle to exhaust. When this has occurred, the live air which is constant in H enters, and another cycle is gone through.

Pneumatic Chuck.—Compressed air has been applied for gripping pieces of work in jigs, as a more rapid and equable method than tightening up bolts. The Pratt & Whitney Co. use it in some of their jigs for clamping pieces of work to be drilled or otherwise machined. In one case bolts are operated by air cylinders, which draw them down against

the work, and hold it securely by the simple movement of an air valve lever, without risk of excessive or uneven pressure being exercised, which might cause the object to be distorted or strained. In another case the air pistons operate rocker arms, pressing against the work, and holding it up against a prepared face which locates it accurately ready for the machining operations.

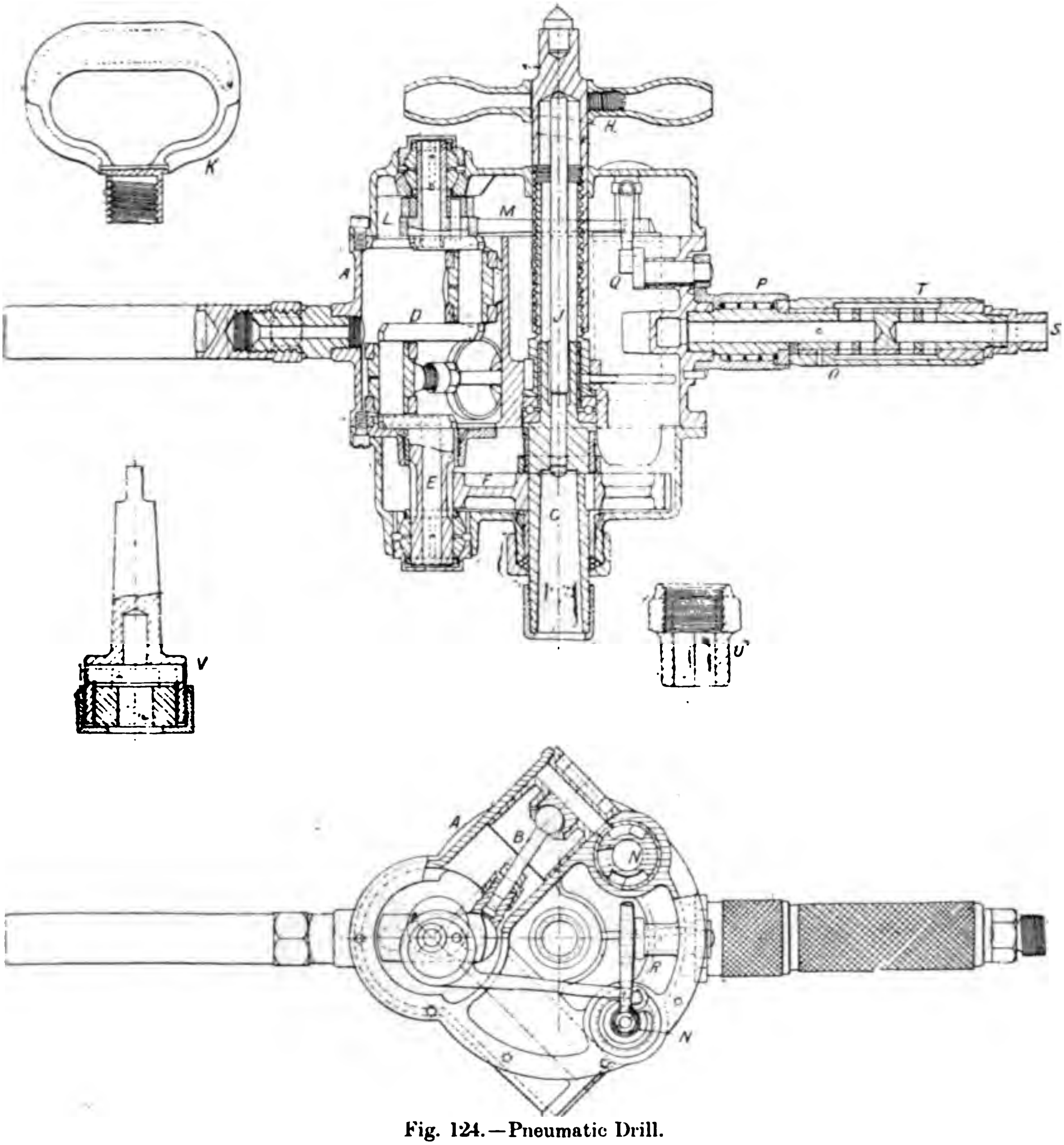


Fig. 124.—Pneumatic Drill.

Pneumatic Drills.—The application of an air motor to driving a portable drilling machine, followed upon that of the early steam machines, which suffered from the troubles inseparable from condensation in the pipes, &c. Air power is much more convenient and economical, although it is rivalled by that of electricity; but when firms have an installation of air-compressing plant for supplying pneumatic hammers, it is generally found that pneumatic drills are also employed. The method of driving

is by means of small cylinders, of fixed or oscillating type, working by connecting rods on to a crankshaft, which is geared to the drill spindle. The small machines have two cylinders, the larger ones frequently four. An example of the former class is given in Fig. 123 from the practice of the Howard Pneumatic Engineering Co., Ltd. The cylinders A, A are of oscillating type, and are worked by the air passing through a valve block B between them, ports being opened and closed by the oscillation of the cylinders on their trunnions. The direction of motion is reversed by altering the handle C, which moves over a quadrant, to which it can be locked by a spring collar, and modifies the positions of the ports in the block B. The air hose is screwed on to the end C, and the supply turned on or off by twisting an outer knurled sleeve, which makes or breaks communication between the two chambers in the handle. The connecting rods of the pistons work on to the crankshaft E, which is coupled by back gears to the drill spindle F, fitted with a ball thrust collar, and a feeding screw G, on which the star handle H and the pointed end allow of pressure being taken from a drilling pillar, or other suitable thrust piece. The ratio of reduction from the crankshaft to the spindle may be varied by substituting different spur wheels on the respective shafts.

Fig. 124 illustrates a four-cylinder machine by the Consolidated Pneumatic Tool Co., Ltd. The cylinders in this case are formed out of the

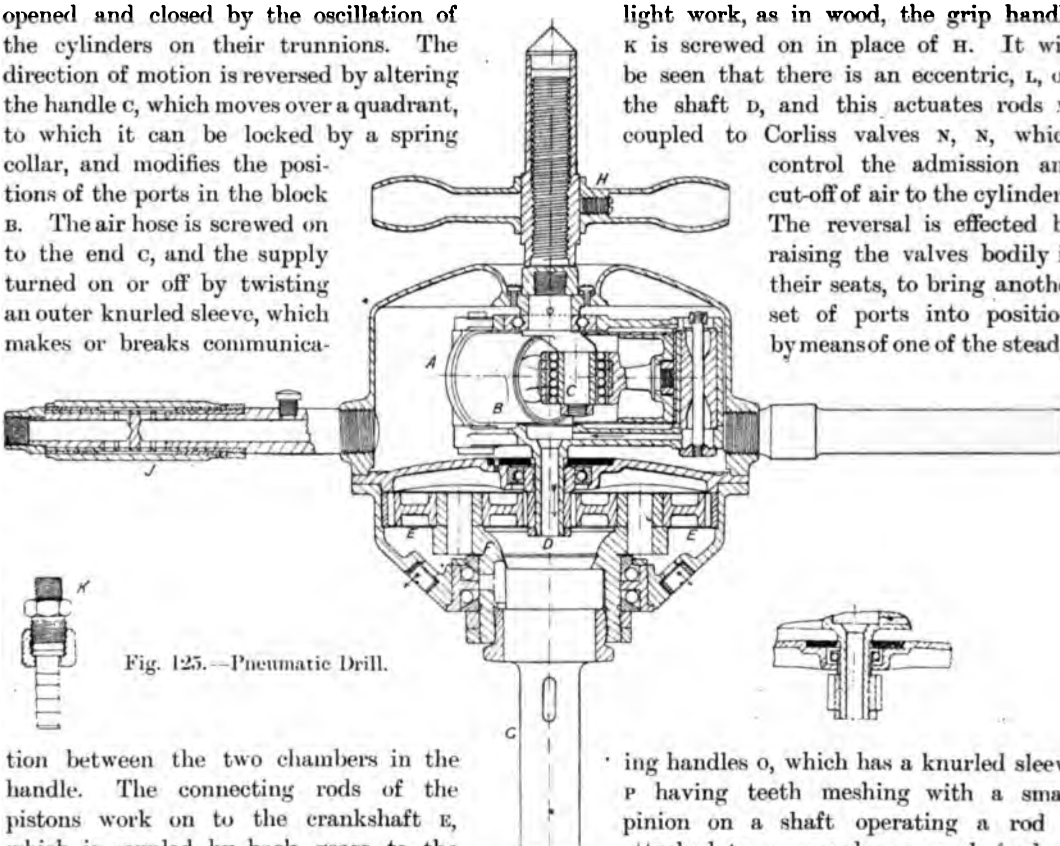


Fig. 125.—Pneumatic Drill.

casing or body, A, and are placed in pairs, at right angles. The pistons B actuate ball-ended connecting rods, which drive the two crankpins of the shaft D, running in spherical bushes at the ends, and also in an intermediate bearing, above a pinion E, driving a wheel F, keyed to the drill spindle G, provided with ball thrust, and feed screw H; an extractor pin J inside enables the operator to eject the drill from the taper hole in G. When the machine is to be employed for light work, as in wood, the grip handle K is screwed on in place of H. It will be seen that there is an eccentric, L, on the shaft D, and this actuates rods M, coupled to Corliss valves N, N, which control the admission and cut-off of air to the cylinders. The reversal is effected by raising the valves bodily in their seats, to bring another set of ports into position, by means of one of the steadying handles O, which has a knurled sleeve P having teeth meshing with a small pinion on a shaft operating a rod Q attached to a cross-bar R, each end of which is connected to the tops of the Corliss valves. The air is brought in through the end S of the handle O, and turned on or off by rotating the sleeve T, which causes sets of drilled holes to open or close. U is a chuck used for holding square shank drills, and V a tapping socket.

These drills are made in six sizes, the smallest having cylinders $1\frac{1}{4}$ in. bore by 1 in. stroke, and the largest $2\frac{3}{8}$ in. by 2 in., developing respectively HP. of 1, and $3\frac{1}{2}$. The spindles

rotate at 600 and 190 revolutions per minute respectively, and the weights are 20 and 70 lb.

A compact and convenient shape of machine is that of the Boyer drill, Fig. 125 (the Consolidated Pneumatic Tool Co., Ltd.), the body A being of circular form without angular projections. There are three single-acting cylinders, B, which move around a fixed crankpin, the pistons being made with short rods fitting with ball bearings to the pin C. The ends of the cylinders B have pivot pins, passing through holes in a frame D which thus rotates. The frame is extended below into a spindle, which is hollow, and fits in a diaphragm plate, through which the air cannot pass. It can only get from the cylinder chamber by going through the cylinders themselves, and then exhausts through narrow passages and out from the hollow spindle extension of D to the atmosphere by way of holes in the lower casing. A pinion fast on the lower end of D engages with wheels E, E, which mesh with a ring of teeth inside the lower casing; these wheels fit over pins in a frame F, and as they run round, revolve F, and from that the central drill spindle G. The usual feed screw is indicated by H, and the handle J serves to control the air supply in a manner already described. The coupling for the flexible hose connecting it to the end of J is shown at K.

The air pressure employed for pneumatic drills ranges from 40 to 80 lb. depending on the character of the work, whether light or heavy. The operations carried out are not necessarily confined to drilling: reaming, countersinking, tapping, and tube expanding are done with machines of various types. When tapping, the drills are held in the hands, with or without the help of a suspending cord, and pushed up sufficiently to let the tap catch; reaming usually requires the use of a drilling pillar, to steady the machine, and to feed from.

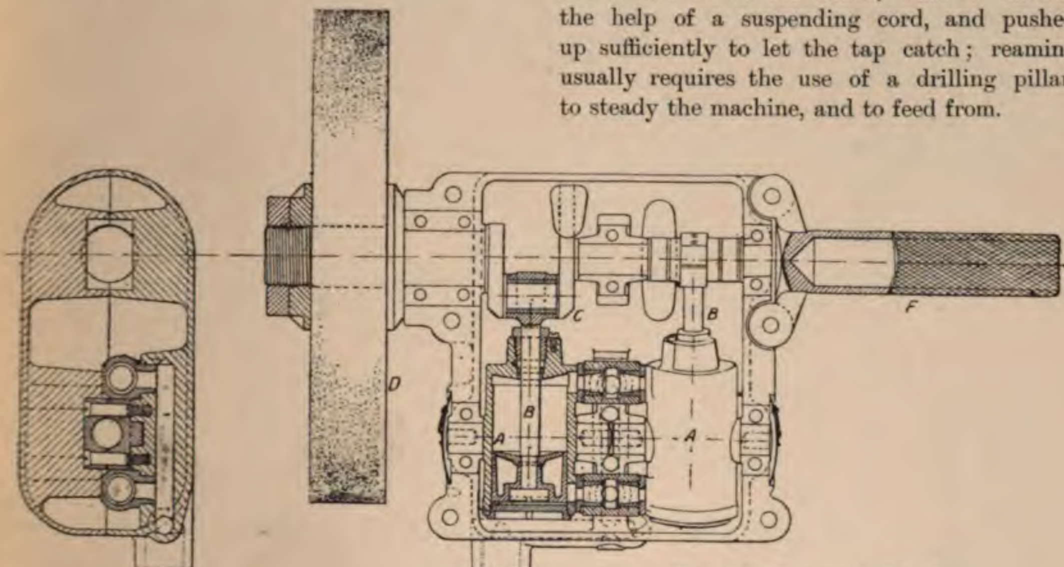


Fig. 126.—Pneumatic Grinder.

Pneumatic Grinding Machines.—These, made of small size, are very handy for fettling and trimming purposes where it is inconvenient or impossible to apply the work to a fixed wheel. The grinders can be carried to the work, and moved about over irregular surfaces with ease. Fig. 126 shows the Whitelaw machine (made by the Consolidated Pneumatic Tool Co., Ltd.), fitted with a 10-in. emery wheel. Here a pair of oscillating cylinders A, A drive by pistons and rods B, B to the crankshaft C, on the enlarged end of which the grinding wheel D is mounted. The handle below admits and controls the air to the ports set between the cylinders, which cover and uncover as they oscillate; the other handle F affords a hold for the workman to steady the machine as it is moved about.

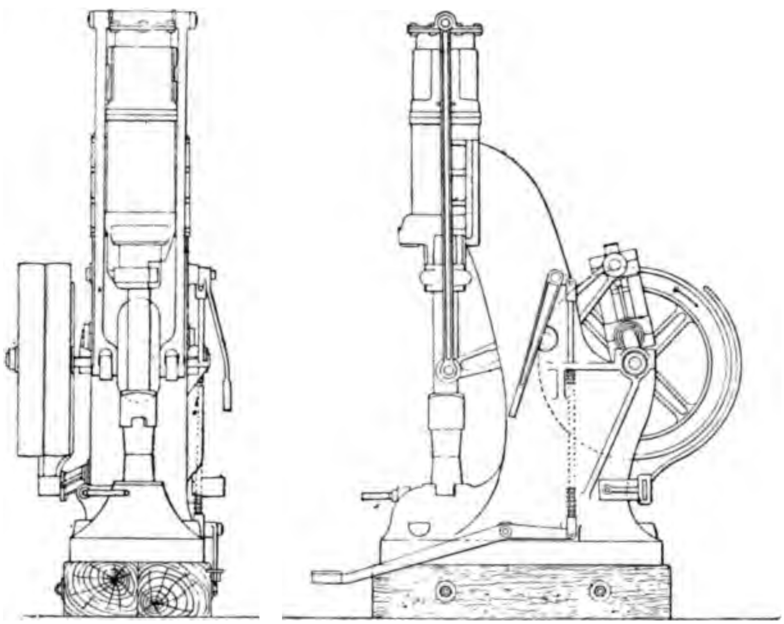


Fig. 127.—Longworth Power Hammer.

Another type of machine is made with the wheel on the centre of the spindle, midway between the frame, and the handles project from each side, giving a balanced hold. Guide facings are often screwed on to control the distance of the wheel from the surface, and enable it to work flat faces, in the same manner that a plane iron is fitted in a body.

Pneumatic Hammer.—These hammers are largely made use of in the smithy. Air, being highly elastic, is an excellent agent in the cushioning of the reciprocating parts, and is readily controllable. The hammers are belt driven from any convenient source of power. But beyond this the different kinds of hammers have few features in common.

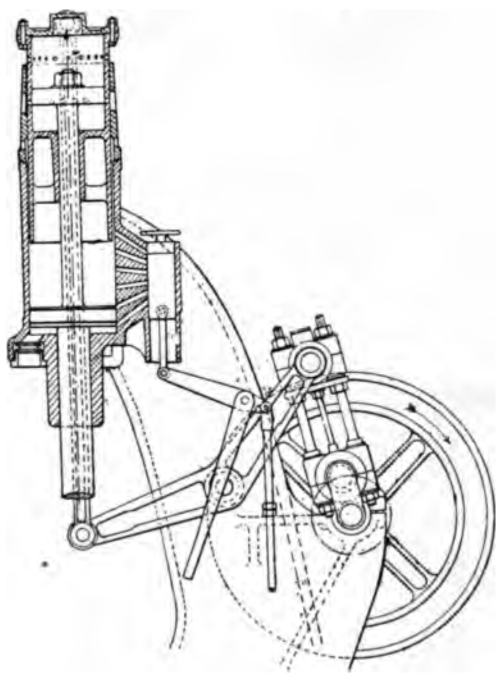


Fig. 128.—Longworth Power Hammer. (Vertical Section through Cylinders.)

In the hammer by Breuer, Schumacher, & Co. a single cylinder is used, and a plunger reciprocated therein alternately compresses and rarefies the air in the cylinder. Variations in the quantity of air admitted are regulated by a cock. The air pressure can be raised to four or five atmospheres. When the cock is wide open, the interior of the cylinder is open to the air, and the hammer piston remains stationary. The plunger only is moved up and down by the crank disc driven from the pulleys, but the hammer or tup is attached to a piston which moves loosely in the bottom of the cylinder, and between the two the air space is left. When the cock is closed, the hammer piston is drawn up. After the crank has turned the top dead centre the air between the plunger and piston is compressed, driving the hammer down with a maximum force of four atmospheres. The air cock supplies the means of regulating the force of the blow without reducing the speed.

The Longworth hammer, Figs. 127 and 128, made by Messrs Samuelson & Co., Ltd., has two cylinders; one, the hammer cylinder containing the piston rod actuating the tup, the other, the controlling cylinder by which the intensity of the blow can be regulated. In the early designs the two cylinders were distinct, arranged tandem, with the controlling cylinder lowermost. In the present type the hammer cylinder is brought within the controlling cylinder, so reducing the total height, *see* Fig. 128. The principle of operation is as follows:—The piston rod which carries the tup at its lower end is prolonged upward to carry a second piston at its upper end. The latter is the *actuating* piston, the former the *controlling* piston. The actuating cylinder moves within the controlling cylinder, and a very deep boss within the former serves as a rigid guide to the piston rod. A series of air ports effect communication between the controlling cylinder and the outer atmosphere. These ports can be opened or closed one or more at a time by a cylindrical plug valve which is actuated by a hand or foot lever. The actuating cylinder is connected by a crosshead and side links to a lever crank, and connecting rod to the belt drive. In action, the movement of the crank

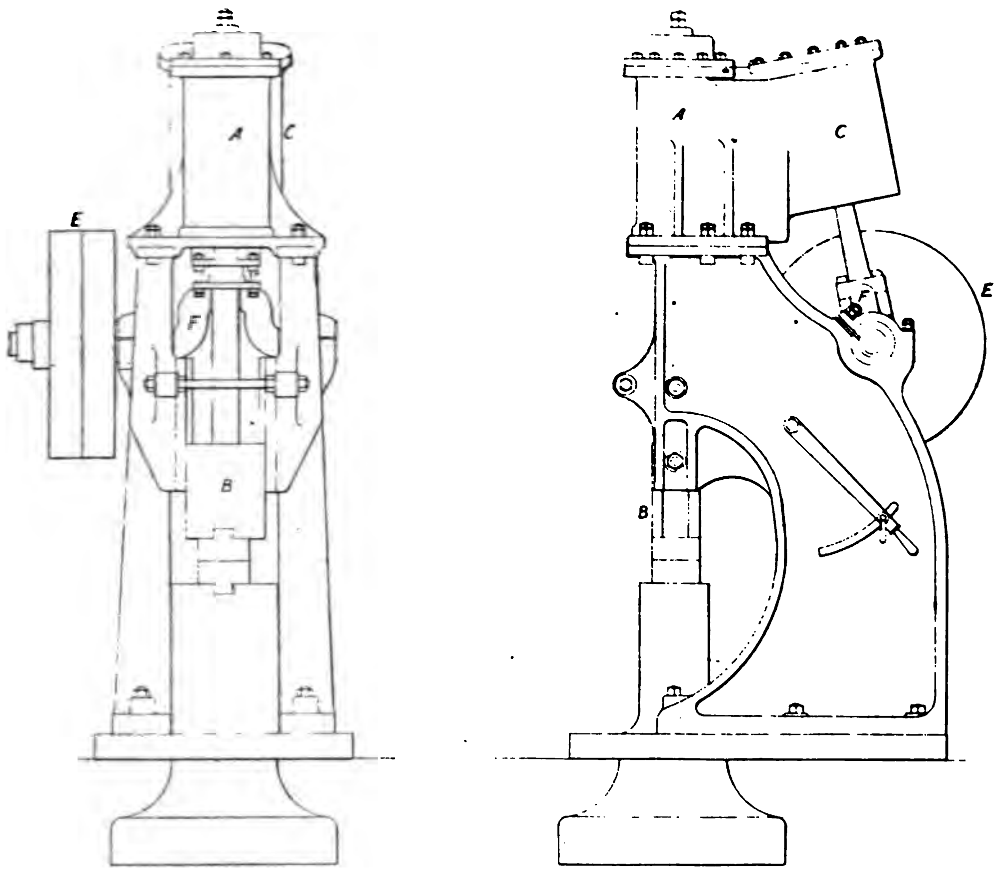
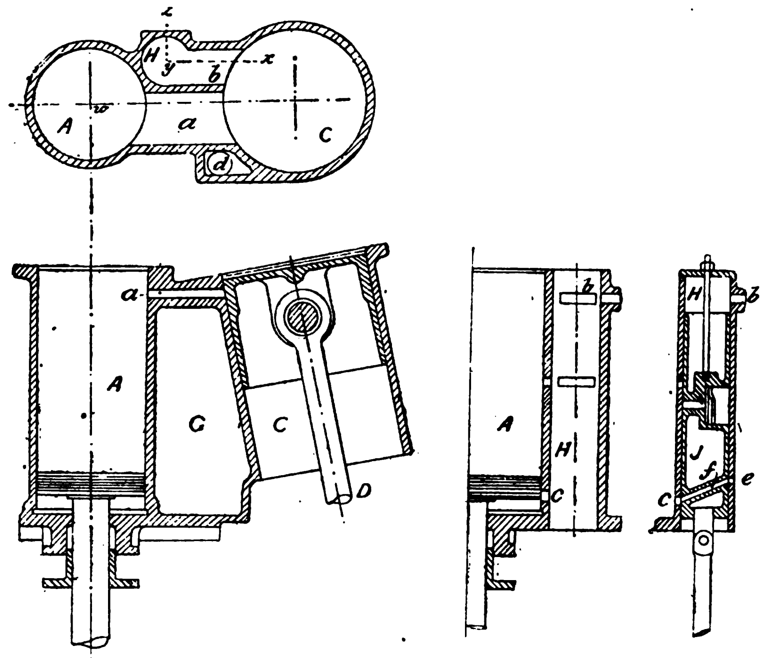


Fig. 129.—Player Pneumatic Hammer.

REFERENCES TO FIGS. 129, 130.

A. Hammer cylinder. *B.* Tup. *C.* Pump cylinder. *D.* Piston of ditto. *E.* Belt pulleys. *F.* Crank. *G.* Air reservoir. *a.* Passage connecting cylinders. *H.* Valve chamber. *J.* Control valve. *b.* Port connecting pump cylinder to atmosphere. *c.* Port connecting hammer cylinder to atmosphere. *d.* Connection of pump to reservoir. *e.* Port from air reservoir to valve chamber. *f.* Passage in valve to connect ports *c* and *e*.

lifts the side links, and the upper or actuating cylinder until its piston cuts off the air at the bottom row of holes. This air being compressed by the continued upward movement of the cylinder lifts the upper piston, and with it the piston rod and tup. When the crank passes the bottom of its stroke, the upper cylinder gains upon the falling piston, closing the top row of air holes. The air thus becomes compressed, and accelerates the motion of the tup. If the lower cylinder is now in free communication with the atmosphere by the opening of the bottom air ports, the tup will fall to its lowest point, and deliver its blow with the fullest force. But if all the air ports are closed, the air below the lower piston will be compressed by its descent, and the tup held up off the anvil.



Section *w-y-z*. Section *x-y-z*.

Fig. 130.—Cylinder Sections of Player Hammer.

The Player hammers, Fig. 129, made by W. & J. Player, have the pump and hammer cylinder distinct, with a separate reservoir G for compressed air. In Figs. 129, 130, A is the hammer cylinder, the piston of which actuates the tup B. C is the pump cylinder, the piston D of which, belt driven from the pulleys E, and crank F, supplies air to the hammer cylinder, and exhausts it therefrom. The passage *a*, Fig. 130, forms the communication between the two cylinders. Air is compressed in the reservoir G also by the pump piston, which happens when the latter runs past the connecting passage *d*, so closing it, when the air imprisoned beyond this passage becomes forced into the reservoir. There is a valve chest H between the two cylinders, the valve J of which permits of communication between the top of the pump cylinder, and the atmosphere at *b*.

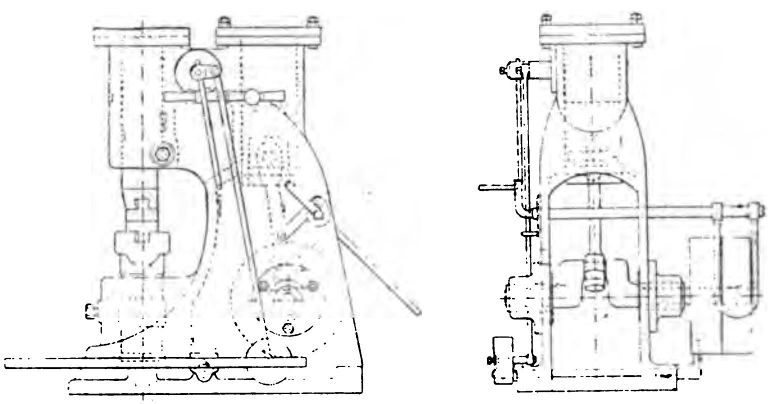


Fig. 131.—Pilkington Power Hammer.

When this valve is open, the action of the pump piston is not communicated to the hammer piston. A passage *c* which makes connection between the bottom of the hammer cylinder and the external atmosphere is controlled by the valve J allowing a free passage for the air, or closing it and imprisoning air beneath the piston, cushioning the blow, or opening the passage to the compressed air reservoir, so holding up the piston at the top of the stroke. In this position the valve at the top of the pump cylinder is open. A volute spring cushions the piston in its ascent.

In Pilkington's hammer, Fig. 131, made by Peter Pilkington, Ltd., the pump cylinder and the hammer cylinder are separate. A cylindrical valve regulates communication between the two through ports in both cylinders. Hand or foot levers operate the valve. The valve is so balanced that its normal or zero position is taken automatically when the levers are released. When the valve is at zero, the tup is held up at its highest position, but when the valve is fully open the pump and hammer cylinders are in communication, and the tup rises and falls. With the valve in intermediate positions, the weight of the blow is varied.

Pneumatic Planishing Hammers.—Fig. 132 illustrates one of this type by Piercy & Co., Ltd. The standard A supports two cylinders B, and C, in one casting. The piston and rod of B drives the hammer head. The cylinder C is horizontal, with a trunk piston D, of short stroke. The cylinders being connected by the passage *a*, a short stroke in C produces a long stroke in B. Driving takes place from the fast and loose pulleys E, stepped cones F and G to the eccentric H, actuating the piston D. The eccentric is of the shifting type, so that any length of stroke within the maximum can be obtained, and any

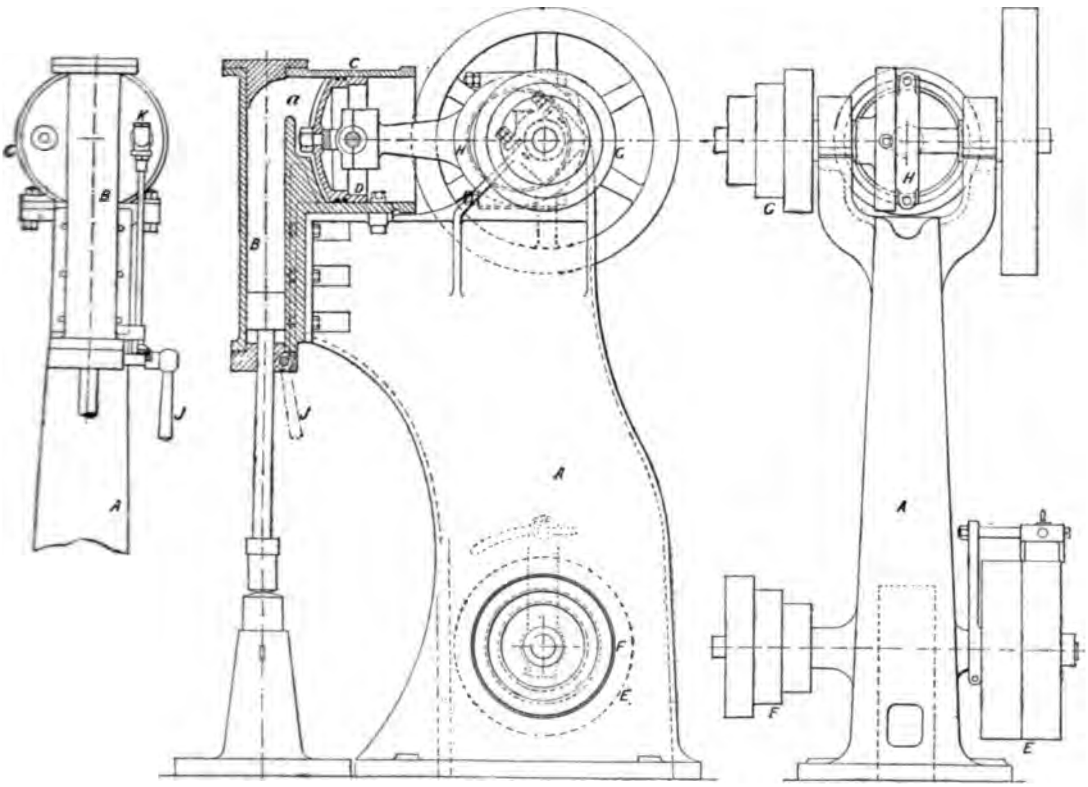


Fig. 132.—Piercy Planishing Hammer.

kind of blow. The movement of the hammer rod in B is obtained by the alternate conditions of semi-vacuum and compression between the two cylinders. More stroke is required for thick copper than for thin. One handle J is used for controlling the action, which starts and stops the hammer, regulates the blow to the force required, and holds the hammer rod up when stopped. It acts on an air cock on the larger cylinder at K. When this is opened wide the piston D draws air in and out freely, without moving the hammer rod. As the cock closes, less air enters, and the hammer begins to work. An inlet valve on the cylinder C is left slightly open to let in a small quantity of air during the upstroke, to prevent the hammer rod from being sucked up too violently. A small outlet valve on the cylinder B lets out the compressed air at the end of each stroke, which had accelerated the previous blow.

Pneumatic Riveting Hammer.—The same class of hammer that is employed for chipping and caulking is also used for riveting, with the difference that a snap is inserted, and that it has a round shank in place of the hexagonal shank on the chipping chisels. A special type of tool is used for heavy riveting, the *long-stroke* hammer, having a long cylinder, which enables a heavier blow to be obtained, in conjunction with a higher air pressure, usually 100 lb. per square inch.

Fig. 133 gives an external and a sectional view of the Tierney hammer, made by the Globe Pneumatic Engineering Co., Ltd. The cylinder A carries the snap B, and the plain piston C. The handle D is screwed to A with a buttress thread, and locked with a split lug and bolt. The trigger E controls the admission of air from the flexible hose coupled to the extension, and

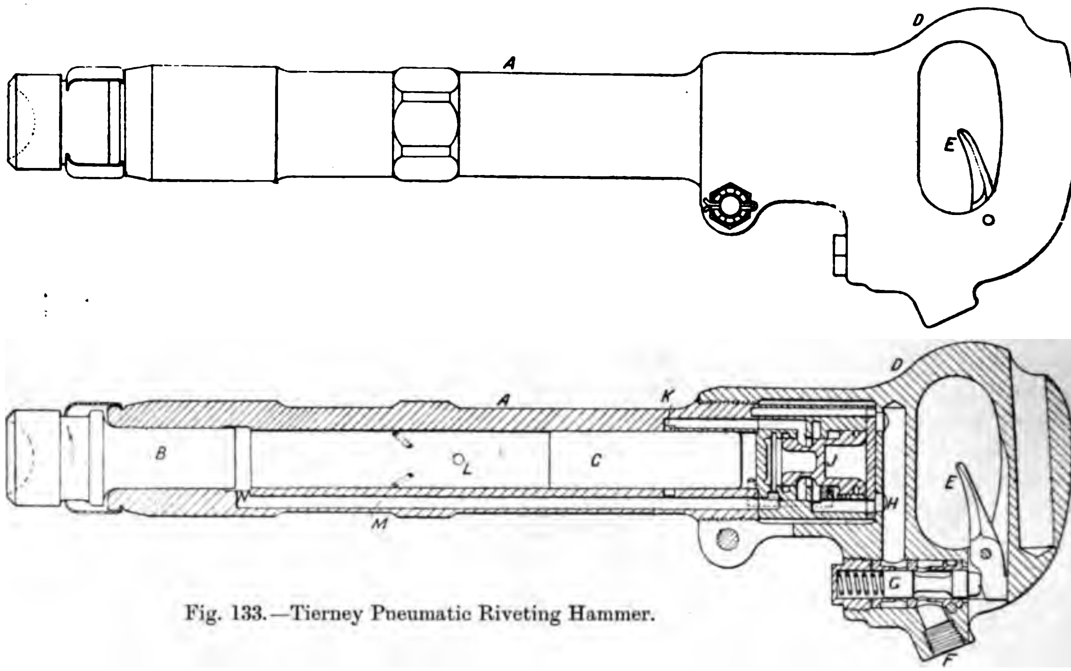


Fig. 133.—Tierney Pneumatic Riveting Hammer.

lets it pass through the valve G, from which it goes up the passage H past the valve J, moving the piston C forwards; when C has uncovered the hole K, air at full pressure rushes through K and drives C sharply against the end of the snap B. At this position the hole L has been uncovered, and the air passes through it down a hole communicating with the valve box, moving the valve so that it opens communication with the passage M, letting air through hole N, and driving the piston backwards, after which another cycle of operations commences.

A time-saving adjunct in connection with

riveters is the pneumatic holder-on, Fig. 134 (the Consolidated Pneumatic Tool Co., Ltd.), employed to support the rivet head while the tail is being turned over. It comprises a casing, A, having a screwed hole at the back, into which a bar is put for support; a throttle handle, B, admits air to the back of a cylinder, C, which moves outwards, pressing the snap D against the rivet head. The attendant then opens the valve E, admitting air to the piston F, and causing it to repeatedly strike D and so beat the rivet into its hole. The riveter on the other side at the same time rivets over the tail. The piston F is then stopped, leaving C still pressed up to take the thrust of riveting, the cushion of air at the back forming a buffer.

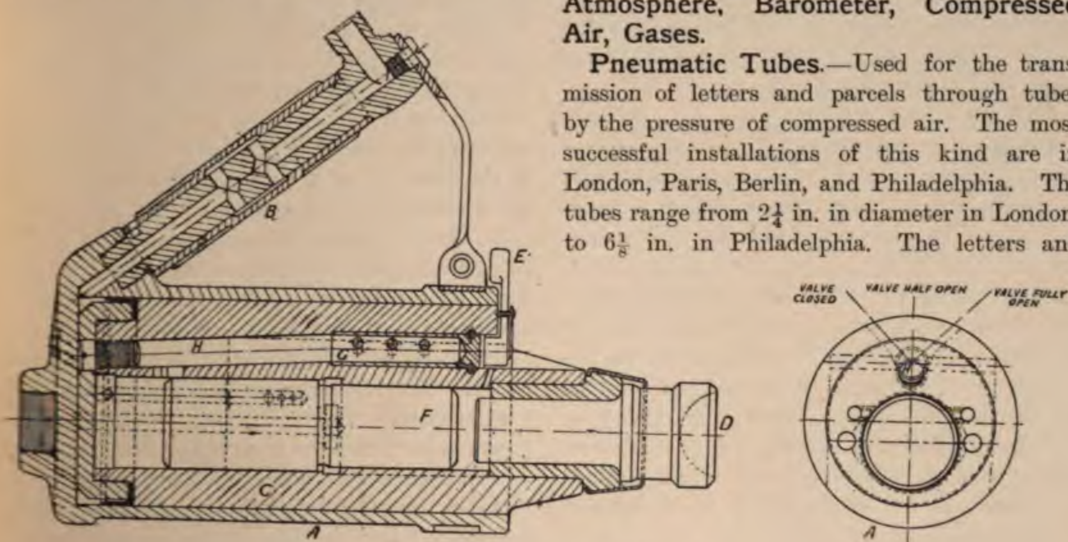


Fig. 134.—Pneumatic Holder-on.

Pneumatics.—Under this term are included all questions that relate to weight, pressure, elasticity, and other properties of air and other gases. During recent years there has been a marked development in the utilisation of these properties in engineering. The elasticity of air has been made use of in coal-cutters and pneumatic tools; caulking, riveting, and similar operations are performed by the aid of compressed air; locomotives are driven by air at high pressure—up to 2,000 lb. per sq. in.; caissons and hydraulic shields and diving bells depend for their use on compressed air; the exhaustion and pressure of air in pipes serves to transmit parcels and despatches or to raise grain in elevators; loads are raised or suspended by the air-hoist; ventilation and heating are simplified by the use of fans and blowers; and the use of pneumatic tyres for cycles and motor cars has given birth to a new and large industry.

The practical application of air in these appliances and machines is dealt with under their several titles, while the theoretical aspect of the behaviour of gases is dealt with under **Adiabatic Curve, Air Thermometer, Atmosphere, Barometer, Compressed Air, Gases.**

Pneumatic Tubes.—Used for the transmission of letters and parcels through tubes by the pressure of compressed air. The most successful installations of this kind are in London, Paris, Berlin, and Philadelphia. The tubes range from $2\frac{1}{4}$ in. in diameter in London, to $6\frac{1}{8}$ in. in Philadelphia. The letters and telegrams in the last-named are enclosed in carriers, $5\frac{1}{4}$ in. diameter, and 18 in. long, with canvas packing which makes them up to $6\frac{3}{32}$ in. diameter, and they weigh $9\frac{1}{2}$ lb. The air is compressed to 7 lb. pressure per sq. in., and passed into a reservoir. It goes thence into the transmitting apparatus, and into the outgoing line of pipe to the receiving apparatus. Just before the carrier enters the latter the air is diverted through the transmitter of the receiving station, and into a return pipe which enters the compressed air reservoir. The air is thus used over and over again, and losses only made up from the atmosphere. Tubes of lead and brass are used in London, of wrought iron in Paris, and Berlin. Those in Philadelphia are of cast-iron pipe, bored smoothly

by a boring head reamer on a flexible bar. The bends used are of 6 ft. radius.

Pocket Print.—*See* **Print.**

Podger.—A **Tommy.**

Poker Filing.—*See* **Draw Filing.**

Polarisation.—Chemical action always accompanies the production of a current in a voltaic cell. The bubbles of hydrogen evolved at the surface of the copper plate adhere to it, and thereby gradually decrease its effective surface. This affects the current both by increasing resistance and by producing an opposing electro-motive force. The differences between various types of cells are mainly due to the methods adopted for minimising polarisation. *See* **Batteries, Primary.**

Poling.—*See* **Copper.**

Polishing Powders.—The fine powders which are used for polishing metal work and microscopic specimens. They include a large number. The commonest are the finest emery powders, and wheels, used for finishing work after grinding to dimensions has been done, and these suffice for all the ordinary work of the shops. When work has to be nickel plated, or lacquered, buffing is commonly practised, in which the buffs are charged with emery or with some other powders as rouge and crocus. Other powders are employed for microscopic specimens and for work that is only partially allied to engineering.

Diamond dust as a polishing agent used by jewellers is not employed by engineers. Alumina is the basis of emery, and rottenstone. Silex is the basis of hones, pumice stones, and tripoli. Oxide of iron is the basis of rouge and crocus; the oxides of tin and lead of putty powders. Crocus and rouge are prepared from crystals of sulphate of iron calcined in crucibles. Portions which are calcined the least form rouge, those which are more calcined form the crocus. There are other methods of preparation. Putty powder is oxide of tin pulverised, or of tin and lead in various proportions. The metal is oxidised in a muffle, and afterwards ground and sifted. Tripoli is a fine earth which consists mainly of silex. It is calcined, ground, and sifted.

The following is Mr Schloesing's method of treating polishing powders for microscopic sections, as given by Le Chatelier. The powders are first treated with water containing one part of nitric acid to 1,000 parts of water, so that the carbonate and sulphate of lime, &c., are dissolved. The mixture is allowed to stand for a few hours, being stirred now and then, after which it is allowed to settle. The liquid is decanted as soon as the powder falls to the bottom. Distilled water is now poured in, and the mixture again stirred, allowed to settle, and again decanted. This is repeated several times, and as the acid becomes removed the settling takes place more slowly, and the liquid is milky. Decantation is done at definite intervals by means of a syphon, the intervals being respectively fifteen minutes, one hour, four hours, twenty-four hours, and eight days. The deposit collected between the first and the eighth day is the true polishing powder, the earlier ones being coarse and unsuitable.

Le Chatelier states that the substances which he found to give the best results are, commercial flour of emery, oxide of chromium, alumina, and oxide of iron.

Polishing powders are often used on laps of metal. The lap forms a matrix for retaining the powder. The softer metals retain the powders best, but lose their shape more rapidly. The materials used are lead and tin, and mixtures of the two; copper, brass, and sometimes cast iron. Buff leather is used on wheels and on sticks to receive and hold the various powders, emery, crocus, or rottenstone. Sometimes the powders are charged with oil. Copper is cleaned with crocus and oil, the oil being afterwards removed with whiting, and final polishing is done with dry crocus, using an old worsted stocking for its application. Glass paper is used by wood-workers similarly to the emery paper and emery cloth of the metal-workers. In each the glass or emery of suitable grade is cemented to the paper or cloth and used in a flexible condition, or laid on rubbers or sticks.

Polishing Wheels.—Wheels built up of segments of wood, around the periphery of which buff leather is gl
polishing powder. Th
on, or simply charged
emery, crocus, rott
are used.

Cloth and cotton wheels are used for final polishing of irregularly shaped articles; the layers of cloth are loose except for the fastenings to the wooden centre, and so accommodate themselves to any shape. The leather used for wheels and buff sticks should be new. Old belting, sometimes used, is charged with gritty matter, which spoils fine polishing with scratches. The best leather is of the same quality that is used for the soles of boots and shoes. The thicker leather is taken from about the neck. Wash leather prepared from sheep skins is employed for hand polishing.

Polygon.—Is a rectilineal figure with more than four sides. It is regular when the sides and angles are all equal; irregular when unequal. A regular polygon can be surrounded by a circle whose circumference passes through all the angles of the figure. The following are the names applied to polygons having the number of sides stated:—

5 sides, a pentagon.
6 ,, a hexagon.
7 ,, a heptagon.
8 ,, an octagon.
9 ,, a nonagon.
10 ,, a decagon.
11 ,, an un-decagon.
12 ,, a duo-decagon.
13 ,, a tri-decagon.
14 ,, a tetra-decagon.
15 ,, a penta-decagon.
16 ,, a hexa-decagon.
17 ,, a hepta-decagon.
18 ,, an octa-decagon.
19 ,, a nona-decagon.
20 ,, a bis-decagon.

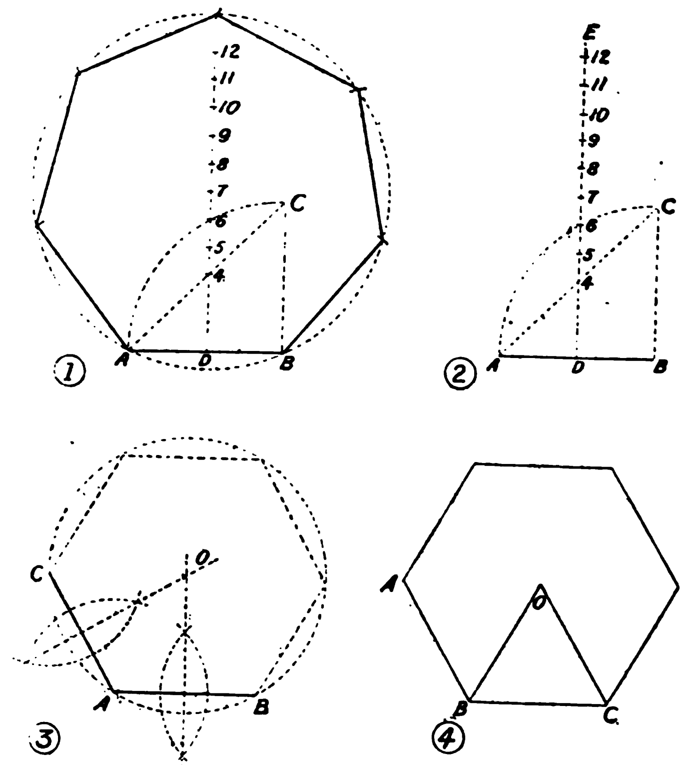


Fig. 135.—Polygons.

Any regular polygon may be described on a given base AB by the following method:—From B, Fig. 135 (1), erect a perpendicular BC, equal to AB. With B as centre and radius BA describe the arc AC. Join the points AC. Bisect AB at D, and erect a perpendicular DE, as in Fig. 135 (2). Mark the points 4 and 6 where this cuts the oblique line and arc respectively. Bisect line 4-6 at point 5. Step off on the perpendicular, spaces equal to 4-5 or 5-6. These points are then centres of polygons having 5, 6, 7, 8, 9, 10, 11, 12 or more sides. Circles are described with these points as centres, the base stepped round the circumference and the points so obtained joined as shown.

Special methods of describing the hexagon, pentagon, octagon, &c., are described under those terms.

When two sides of a polygon AB, AC are given, the figure may be completed by bisecting these sides and producing the perpendiculars (Fig. 135 (3)) till they intersect at O, the centre of the figure.

To find the area of any regular polygon multiply the sum of the sides by half of the perpendicular (drawn from the centre to one of the sides).

Or multiply the square of the side by the number under "Area" in the table on p. 120. The same table also gives numbers by which the side of a polygon should be multiplied to find the radii of inscribed and circumscribed

circles, and also the number of degrees in the angle O (Fig. 135 (4)) at the centre, and the angle ABC contained by two sides.

REGULAR POLYGONS.

No. of Sides.	Name.	Area = Side² × :—	Radius of Circumscribed Circle = Side × :—	Radius of Inscribed Circle = Side × :—	Angle at O.	Angle ABC.
4	Square	1	·7071	·5	90	90
5	Pentagon	1·7205	·8506	·6882	72	108
6	Hexagon	2·5981	1·0000	·8660	60	120
7	Heptagon	3·6339	1·1524	1·0383	$51\frac{3}{7}$	$128\frac{4}{7}$
8	Octagon	4·8284	1·3066	1·2071	45	135
9	Nonagon	6·1818	1·4619	1·3737	40	140
10	Decagon	7·6942	1·6180	1·5388	36	144
11	Undecagon	9·3656	1·7747	1·7028	$32\frac{8}{11}$	$147\frac{3}{11}$
12	Duodecagon	11·1962	1·9319	1·8660	30	150

Polygon of Forces.—*See* **Force.**

Polyphase Currents.—Alternating electric currents differing in phase from each other by equal increments of a complete cycle of alternation or period.

Polyphase or Multiphase currents are produced in an alternator by adding to the number of coils upon its armature, so that several distinct currents are produced in the same direction during one period of alternation. The currents attain their maximum value at instants differing by a quarter, an eighth, or other proportion of a period, depending upon the number of phase windings. So that the effect is that with, say, three phases, three currents are being impressed upon the circuit at the same time, each lagging or following behind the other. Their exact relation to each other in value and time is constant throughout, and upon reversal, so that they are said to be "In phase." The theory of alternating current generation is described under **Alternating Currents** and the diagrams there given illustrate the phases and wave forms of the current in alternating circuits.

Two, three, and six phases are commonly used for power transmission, but the number of phases may be suited to the requirements, the generators being wound accordingly.

Polyphase Motor.—An electric motor in which rotation of the shaft is produced by the rotating magnetic field created by the multiphase current applied to the stator. *See* **Induction Motor, Three-phase Motor.**

Pony Gear.—*See* **Horse Gear.**

Poplar (*Populus*).—A group of trees nearly confined to the North Temperate Zone. The white poplar, or Abele (*Populus alba*), is generally understood when the term is used. The wood is white, soft, straight grained, tough, and not very liable to split. If thoroughly seasoned it may be used for turned patterns, but it shrinks much in drying. A cubic foot dry weighs about 33 lb.; its transverse strength is 550 lb., being the weight required to break a beam 1 in. square, and 1 ft. between supports.

Poppets.—Signifies the hinder supports to work carried between centres in a lathe or grinding machine. Other synonyms are the popit, of the older writers; the back poppet, the movable poppet, both being terms which distinguish it from the front or fixed poppet, more properly termed the headstock, or the fast head. It is also termed the sliding head, the tailstock, the tailblock, and the footblock, the last three being chiefly Americanisms.

The poppet is movable along the bed, on which it can be clamped in any position to suit pieces of work of variable lengths. Fine adjustments are effected by the movement of the

mandrel or spindle on the coned end of which the work rotates. These are the broad features which all poppets have in common: Figs. 136

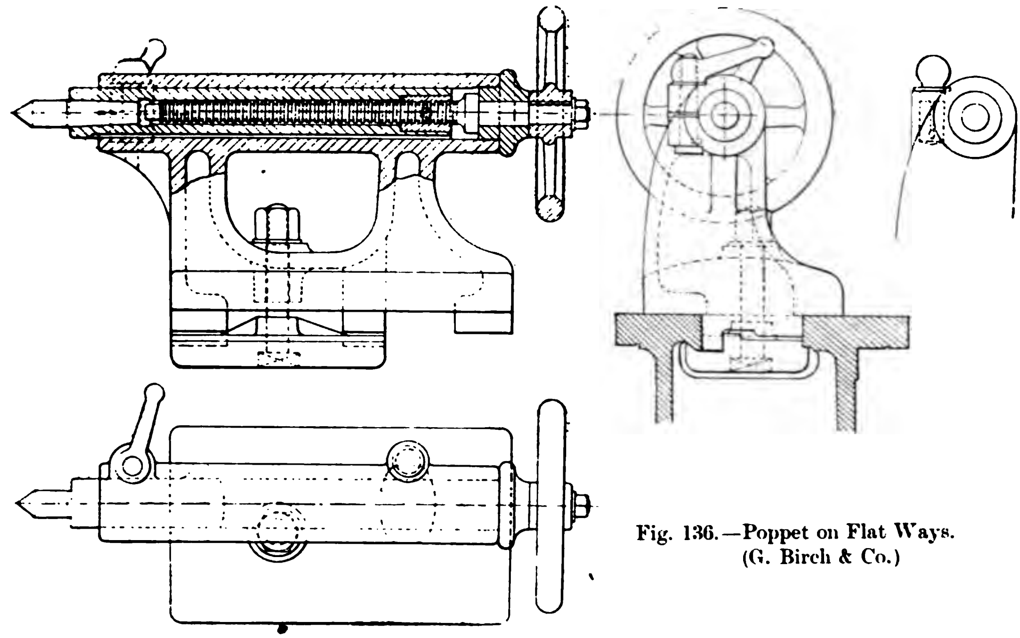


Fig. 136.—Poppet on Flat Ways. (G. Birch & Co.)

to 138, but details of construction vary in dozens of ways.

Alignment, and Set-over Devices.—The alignment of the poppet with the fast headstock is secured by the fitting of the base to the bed. Generally in lathes of small and medium dimen-

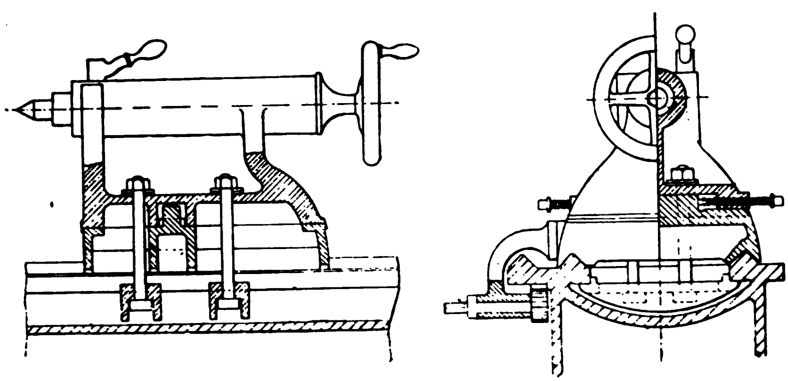
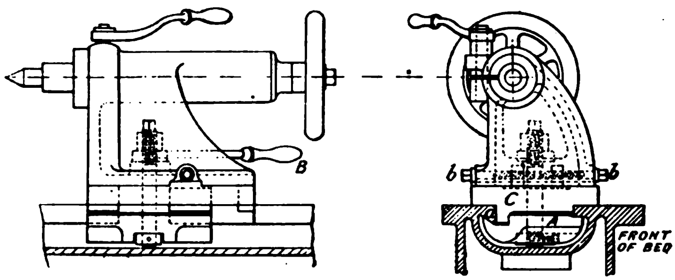


Fig. 137.—Poppet on Raised Vees, and with Set-over.

sions, a tongue alone fitting between the machined ways affords the necessary guidance and coercion in English types, and in American the raised vees. Each has its advocates. In both, the assumption is made that lateral wear will never take place to any serious amount. This is readily conceded in the case of the vees, but not in that of the tongue fitting between vertical edges. To avoid this, in some designs, the tongue is pulled over against one edge always, leaving the other slack. It is done by having an inserted vee underneath one shear, and pulling the clamping plate up against that, Figs. 136, 138, and this, by means of a shouldered fitting, pulls the poppet over against one edge.

The Set-over.—Many English poppets have provision for setting over out of centre for the

turning of tapered work. Most American ones have some provision of this kind, Figs. 137, 138. The design involves dividing the poppet body into two portions, a base, and a top, with provision for sliding the latter on the former transversely to the axis of the lathe, and adjusting the position of the top on the base. Screws are used for setting over, and the bolts which clamp the poppet to the bed pass through both top and base, and serve thus to secure the two together. The necessary slot holes for the bolts, to permit of the traverse, are cast in the base or the top, usually in the former. The joint between top and base is made in a large



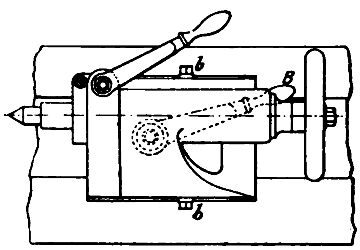


Fig. 138.—The Richards' Poppet.

range of heights, and seems a detail of no importance.

General Outlines.—In the most common designs the poppet is symmetrical on each side of the longitudinal axis, Fig. 137. The edges of the ribs are often concave to allow freedom of movement for the handles of the slide rest. In a good many designs the purpose is further served by cutting away more from the front ribs, and adding more to the hinder ones, Fig. 136. The longitudinal shape of the poppet and the position of the hold-down bolt are designed in order to avoid chance of the poppet lifting at the front under the stress of heavy cutting, or bending at the front with heavy work. The bolt is generally put out of centre, and nearer to the front than the back, and the base is extended at the back, both affording the stability required. The foot is massive, and connected to the barrel with curved brackets with large flowing curves.

The Mandrels.—These are variously operated. The screw turns within one end of the barrel, Fig. 136, and is itself retained from endlong movement by means of a collar filling a recess in the back end of the barrel, and held with a plate, or the boss of the hand-wheel. The mandrel is prevented from turning in the barrel by a setscrew entering a keyway cut along a portion of the length of the mandrel, and by which its length of traverse is determined. The mandrel is clamped through split lugs on the barrel by a clamping screw, or by means of a clamping piece which embraces, or partly embraces the mandrel. The mandrel screw is turned either by a hand-wheel, or a balanced lever handle, balanced with a ball at the end opposite to the operating handle. The cone centre of the mandrel is distinct from the mandrel itself, fitting therein by a shank of Morse, or other taper. It has to be hardened, and should therefore be ground up in its place. It is shot out by the end of the screw.

In the Richards' poppet, Fig. 138, the centre of the mandrel is thrown over behind the axial centre of the bed, with the object of bringing the stresses of turning within the bed. The clamping is like that of the Sellers', the plate A pulling against an inverted vee *a*, the tongue on the base fitting freely within the shears, and being pulled over against one edge. B is the clamping handle. The poppet is of the set-over type, two separate screws *b*, *b* being employed, moving in lugs which stand up from the base C.

Poppets for Grinders.—These differ in an important detail from those used for lathes, in the fact that the pressure against the spindle is taken by a spring. This allows of slight variation in length of work consequent on change of temperature, without which provision long and

slender pieces would spring and cause inaccuracy. Many spindles are operated with a lever, others with a screw.

In the design by Birch & Co., Fig. 139, the tension spring arrangement with its means of adjustment is embodied. The downward pressure of the hand lever draws back the spindle, compressing the spring. For heavy work the spindle is locked by the handle and screw in the split lug. For light work its tension can be relieved by the nut at the end. The screw in the split lug is provided to make adjustments of the spindle for wear.

Poppets are also the nearly vertical members of the cradle used for launching vessels. *See* **Launching**.

Porosity.—The quality possessed by matter of having pores. These are visible in such a substance as pumice stone, but experiment goes to prove that in no kind of matter are the particles in absolute contact. Water has been forced through sheets of gold and silver, and it is well known that quantities of water and alcohol mixed together occupy a smaller bulk than their total separate volumes.

Portable Cranes. — Denotes any crane which is mounted on a truck with wheels, and is thus capable of being hauled along rails or roads, but which has no provision for self-propulsion. It does not therefore denote any special type of superstructure, or any single method of operation, but simply distinguishes it from the fixed cranes on the one hand, and the locomotive cranes on the other. Almost invariably a portable crane is a balance crane.

Portable Engine.—Any engine which is not fixed in the sense in which the stationary engines are fixed, on the one hand, and which is not a self-propelling locomotive on the other.

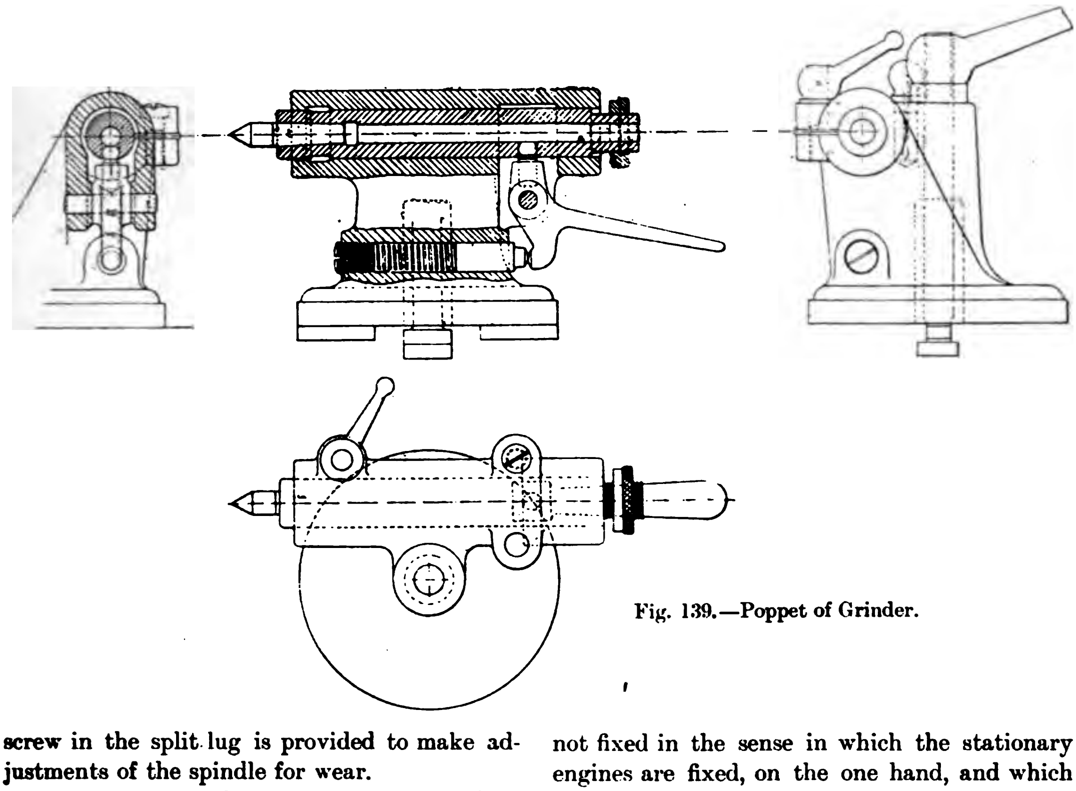


Fig. 139.—Poppet of Grinder.

Simple Portable Engines.—Any simple single cylinder horizontal, or vertical engine, preferably of non-condensing type, can be taken and mounted on a wheeled truck, and so rendered portable. These are therefore used largely by builders, contractors, and engineers on outdoor erections, and by agriculturists for thrashing, grinding, and all kinds of operations about the farm. The flywheel or a pulley adjacent is simply belted up to the machine which it is required to operate, for mixing mortar, sawing

wood, or lifting loads. A horse or two horses will drag the engine anywhere in readiness for service. The boiler is an essential adjunct to get up steam on the spot. In these portable engines the boiler is always of vertical type, bolted down to the truck. The engine is usually bolted independently to the truck, but sometimes it is bolted to the boiler itself. A special development of these portable engines is the hoisting engine (*see* **Hoisting Engines**); this is an engine on a truck with the addition of a hoisting drum or drums operated by the engine. A rope or chain wound on the drum operates a hoisting crab, independent, but somewhere adjacent, and thus erections out of doors are done, power hoisting taking the place of winch handles and human labour.

Generally the term portable engine is understood to signify the *agricultural* engine in which a multitubular locomotive boiler is used, to which the engine is attached. The portable engine drives to a dip crank, on one end of which a heavy flywheel is mounted, the rim of which takes the place of the driving belt. Portable and traction engines are both *road* engines, so termed because they are designed to run on common roads. They are built after the broad designs of locomotive engines, modified to suit the altered conditions of service. The first difference between the traction and the portable types is that the first are self-propelling and are used for haulage on roads, the second require horse haulage. Both, however, are employed for thrashing, and other operations in agriculture, and for electric lighting, pumping, &c. Both fulfil the function of a stationary engine, but are rendered portable in order to serve all localities of a large farm, or several farms in a district, or to haul trains of wagons.

The locomotive type of boiler mounted on wheels, with engines simple or compound, and the motion work above the boiler is the leading characteristic of both traction and portable engines. The essential differences are those due to the arrangements for self-propulsion and steering in the first named. The hinder, which are the driving, wheels are gear-driven at two speeds, either set of wheels being thrown in or out with a locking pin. In the quick gear the engine runs at about four miles an hour, on level and smooth roads, in the slow gear at about two miles for hill-climbing and heavy haulage. The wheels are built up with wrought-steel arms riveted into boss and rim. The arms are frequently cast into the rim and boss.

In the portable steam engines by Messrs Ruston, Proctor, & Co., Ltd., the cylinder is not bolted directly to the boiler, but to an intermediate seating of steel. The latter is riveted to the boiler similarly to the seatings for manholes and other fittings. The seating having its edges caulked does not leak, and the cylinder foot being planed to meet the face of the seating, also planed, does not leak. The cylinder is jacketed by the fitting of a liner of hard iron within the body. Live steam is admitted to this jacket through a hole in the boiler beneath. The advantage is that the jacket steam is dry, because the jacket is a portion of the steam space in the boiler, which is better than using a pipe. The cylinder is maintained at a high temperature, and with the minimum of condensation of steam. A single-cylinder portable engine is illustrated by Fig. 140, Plate IX. The cylinder is jacketed, the guide-bars are of flat type, and a bent crankshaft is employed, the bearings for which are supported in wrought-iron brackets riveted to the boiler. The feed pump is seen at the side, below one bearing bracket, together with its suction tube and strainer.

Fig. 141, Plate X., shows a compound engine, with the cylinders constructed and fitted, as just described.

Compound Engines.—Compounding on portable engines saves from 15 to 20 per cent. in fuel, provided the steam is generated at a pressure of about 130 lb. per square inch. Diagrams taken show that if steam is admitted into the high-pressure cylinder at 130 lb. and cut off at approximately one-fourth of the stroke, it expands down to about 38 lb. at the termination of the stroke. Entering the low-pressure cylinder at this pressure, this cylinder having a capacity of two and a half times that of the high-pressure one, it expands down to about 6 lb., at which it exhausts into the atmosphere.

It is usual to cast the two cylinders together. The guides, of cylindrical shape, are cast in one

Fig. 141.—Compound Portable Engine. (Ruston, Proctor, & Co., Ltd.)

Fig. 142.—Floor Plate in the Works of the Electric Construction Co., Ltd.

To face page 124.

piece with their cylinder, and are sustained at the front end by a bracket which is riveted to the boiler. There are numbers of portable engines with two cylinders that are not compounded. They simply have cylinders of equal sizes duplicated side by side, and driving to one crankshaft with the crankpins at right angles with each other. The advantage is that of easy starting and steady running consequent on the absence of dead centres.

Many portable engines are made with a jet condenser. Its use saves fuel when sufficient water is available. But a very tall chimney is required, from 40 to 60 feet high, because the exhaustion of the waste steam through the blast pipe has to be sacrificed. The condenser is attached to one side of the boiler.

Spark arresters are fitted to portable steam engines used for agricultural work, to prevent risk of damage by fire. The simplest is a cage of wire attached to the top of the chimney. But the best are those with a water pocket and a baffle plate or damper above, the combination being fitted to the top of the chimney. The water is contained in an annular vessel above, which is a baffle plate that throws the sparks down into the water, where they are extinguished. The water is supplied from the feed pump, and a tap is provided for letting the water out before lowering the chimney. In another type, the Strube, a conical disc is suspended over the centre of the chimney, which deflects the sparks downwards. A weather vane and guard outside prevent the sparks from being drawn out of the chimney by the wind.

Portable Machine Tools.—A large class of machines designed so that they can be transported to and from work, instead of carrying the latter about, as is the case when using fixed machine tools. The advantages are most apparent when dealing with very massive pieces which bear a large proportion in mass by comparison with the portable machines; the mere matter of cranage expense is a serious item, to say nothing of the difficulties involved in setting and adjusting such heavy pieces. It is a comparatively simple matter, however, to fix a small machine on or to the job. In shops that deal regularly with the large castings required for electrical, marine, and engine work, floor plates are laid down, having a good expanse of planed surface, with tee-slots, by which the work is secured, while various portable machines are located around and clamped on the plate. These machines comprise drills, borers, planers, shapers, slotters, millers. The first are generally of radial pattern, the second of horizontal type. Planers have horizontal slides, which can be angled, the shapers being built very similarly. The slotters carry tool-boxes sliding upon a vertical column. The methods of driving these tools are in nearly all cases by electricity, a drive which avoids the trouble and annoyance of flying belts and ropes about the plate. Some examples of portable tools are shown in the photographs, Figs. 142 to 144.

The machines employed for clamping direct to the work include drills, planers or shapers, slotters, milling, and grinding machines. And there are also those held in the hand, such as the smaller pneumatic and electric drills, hammers, &c. Portable keyseaters are also used in cases where a shaft is fixed in an awkward position, and is troublesome to remove and replace. To save the hand work which would otherwise be necessary, a machine is clamped to the shaft, carrying a revolving milling cutter which ploughs out the spline, the cutter being hand-driven. Keyseaters for pulleys and wheels are also numerous; they have a reciprocating tool bar which is racked to and fro inside the wheel bore, to operate the cutter. There is no limit to the diameter of work which can be thus slotted, as there is in the case of an ordinary slotting machine. Hand driving is quite suitable for working many of the light tools, and in fact is more convenient than any other method, because it would often be inconvenient or impossible to bring a source of power to the tool in out-of-the-way situations.

Fig. 142, Plate X., shows a large dynamo ring laid on a floor plate for machining; it also illustrates how space is economised by putting a smaller armature ring inside, and operating on it with a portable drilling machine bolted to the plate. The ring is mounted on a shaft held in a base casting, so that it can be revolved to bring successive portions of the periphery around for drilling.

In Fig. 143, Plate XI., a favourite method of driving small portable drills is shown. An electric motor supported on running wheels drives two short spindles, from which telescopic shafts with universal joints extend out to the drilling heads, also fitted with universal joints. The whole arrangement is very handy, permitting of great mobility and accommodation to the work. The drill spindles are driven with worm gearing inside the casing, and are fed down by hand-wheel and screw. The slotted bases are bolted to the work in any position —horizontal, vertical, or angular. Another method of communicating motion from a motor to a drilling head is represented in Fig. 144, Plate XI. The motor is supported on trunnions in the bearings of a portable trolley, so that it can tilt to suit the angle of the driving shaft; the latter is splined and passes a spur gear driven by a pinion on the armature shaft. This long shaft is therefore free to slide in or out to suit the distance apart of motor and drill head. The connection at the latter is effected through bevel gears, on a swivel bearing. A switch located on the head enables the operator to start and stop the motor. See also descriptions of pneumatic tools.

Portal Crane.—A type for wharf service which has developed extensively in recent years, taking the place formerly occupied by the hydraulic wharf cranes, and steam gantry cranes. They are nearly all actuated by electricity, which for this service is better than either of the agencies just named. They are gantry cranes, spanning the wharf, and so permitting of the passage of trucks and railway wagons underneath. The crane itself may be simply pivoted on the gantry, or it may also have a range of travel thereon. In strictness a portal crane has a small span, and a gantry a larger one. Germany is the home of these cranes, where they are seen in large numbers at all great ports. They are becoming familiar also in Great Britain.

Figs. 145, 146 illustrate a portal crane by the Maschinenfabrik Augsburg-Nürnberg A.G. Twenty of these were supplied for the port of Antwerp. The gantries of cranes of this kind are generally moved along the wharf by hand gear connected to one of the running wheels. In some designs the motor which actuates the slewing gear is also made to travel the gantry. Two motors are fitted, one for hoisting, the other for slewing. The *half-portal*, or *angle portal* crane has only one leg, the place of the other leg being taken by running wheels on the other end of the gantry. These travel on a runway built on corbels along the warehouse frontages. Cross working

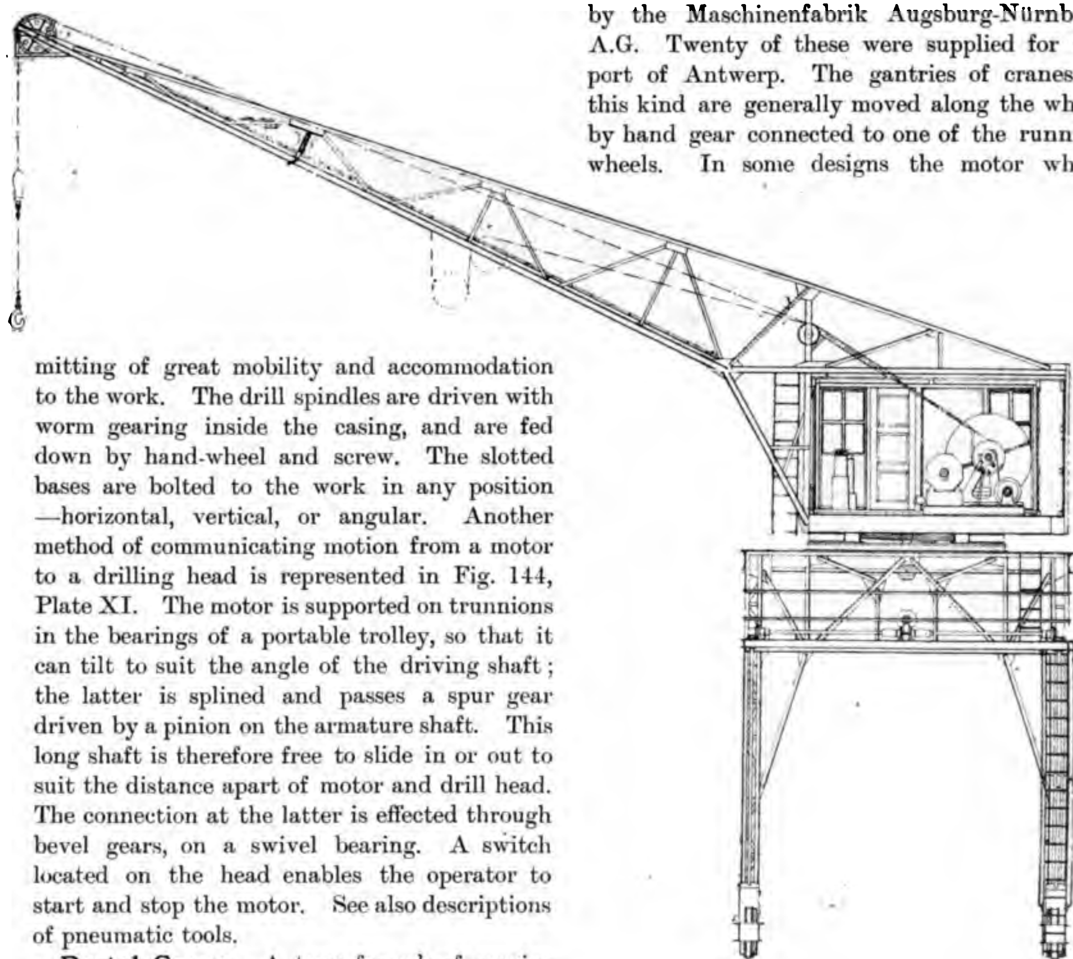


Fig. 145.—Portal Crane. (Elevation.)

is avoided by having a good wheel base. Lightness is studied in the framings by using bracing extensively. The details of these cranes are similar to those of other electric cranes.

Porter-Allen Engine.—The design of Mr C. T. Porter, in which, for the first time, the momentum of a reciprocating engine was utilised for the production of high speeds. He adopted piston speeds which were three or four times higher than those which had been previously employed.

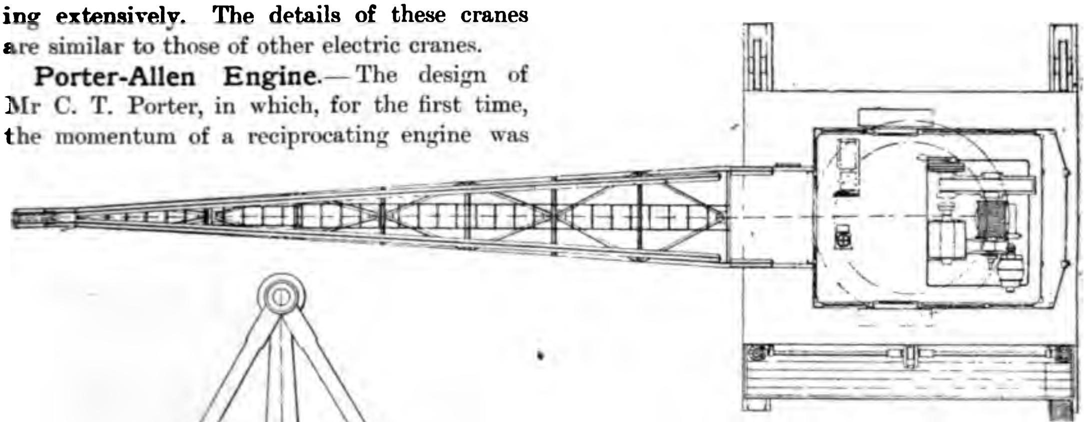


Fig. 146.—Portal Crane. (Plan.)

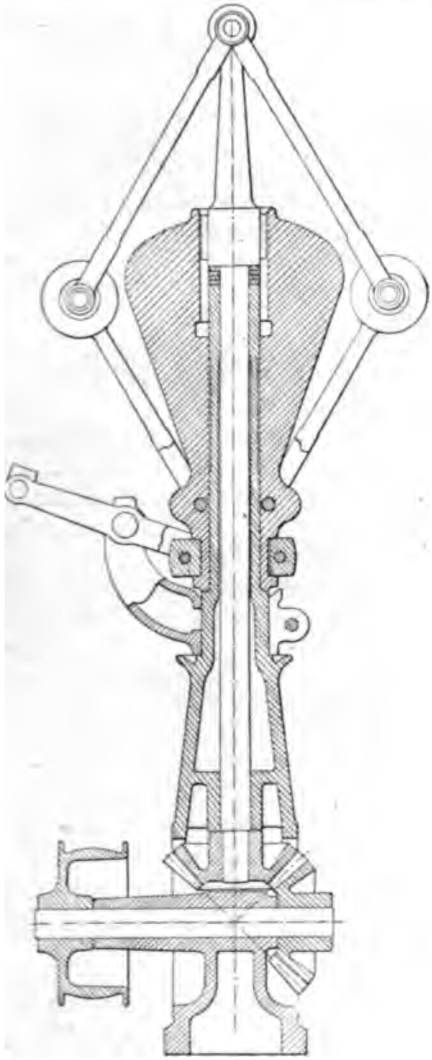


Fig. 147.—Porter Governor.

Porter, Porter Bar.—A long handle attached to a short piece of forging, by which the latter is held and manipulated. The porter may be welded temporarily to the forging, or the latter can be forged from a long bar, and cut off afterwards.

Porter Governor, or **Centre Weight Governor.**—This is so designed to avoid the heavy balls of the ordinary pendulum governors. In this design, Fig. 147, as made by Tangyes, Ltd., the sleeve to which the lower pair of links of the balls is attached is loaded with a heavy weight (or in other designs by a spring). The design is such that the weight is raised about twice the height of that of the balls, and the sensitiveness is about twice that of the ordinary pendulum governor. A high rate of rotation is also practicable. The spring form of loaded governor is often preferred to the original Porter, with a weight. The spring acts more quickly, and cushions any sudden movement, but the strength of the spring varies with its degree of compression. On the other hand, the spring may occupy any position other than the vertical.

Portland Cement.—*See* **Cement.**

Ports.—The openings of the steam and exhaust passages of engine cylinders. The openings to the air and gas passages of regenerative furnaces.

Porty.—A term applied by pipe makers to a print of large dimensions.

Positive.—Besides the application of the term to electric phenomena, and in mathematics, it is used to signify the exact and precise motion of a portion of mechanism, such as a pitch chain, or toothed gears, or of a series of levers; in opposition to that of a belt, which is liable to slip. Positive stresses are those which are compressive in character.

Pot.—The term generally applied by steel melters and brass casters to their crucibles.

Potash.—Caustic potash, or potassium hydrate, KHO, is a crystalline, white, and extremely deliquescent solid, soluble in half its weight of water. It has a powerful caustic action on the skin. It is prepared by boiling a 10 per cent. solution of potassium carbonate and adding slaked lime:—$K_2CO_3 + CaH_2O_2 = 2KHO + CaCO_3$. After subsidence the liquor is drawn off, evaporated, fused, and cast into the familiar white sticks. It is used in the manufacture of soap.

Potash Hardening.—*See* **Case Hardening.**

Potassium (K; 39·15; sp. gr. of solid, ·865; sp. heat, ·166; melting point, 62·5).—Potassium is a bright, silver-white metal, soft enough to be cut with a knife, but brittle at 0°. Heated to red heat it volatilises with a green coloured vapour. Potassium has such a strong affinity for oxygen that it is necessary to keep it in naphtha. So rapidly does it oxidise that its bright metallic surface is only seen immediately after cutting. It decomposes water, forming the hydrate KHO, and the temperature of the reaction is sufficiently high to ignite the hydrogen evolved. It also combines directly with sulphur, phosphorus, and chlorine. Potassium never occurs free in Nature, but is prepared by the reduction of potassium carbonate with charcoal. The two chief oxides are the monoxide K_2O, and the hydroxide KHO, also called potash or caustic potash. The chief salts are neutral potassium carbonate, K_2CO_3; acid potassium carbonate, $KHCO_3$; potassium nitrate or saltpetre, KNO_3; potassium chlorate, $KClO_3$; potassium iodide, KI; potassium bromide, KBr; potassium sulphate, K_2SO_4.

Potatoes.—These are often introduced into steam boilers to prevent incrustation.

Pot Metal.—A cheap brass, of variable and uncertain composition, melted up from poor scrap, or a mixture containing a large quantity of lead, in some cases equalling half the amount of copper present. In such a proportion, the lead partially liquates in cooling, and the term *wet* pot metal is used to designate it. Pot metal is improved by additions of tin, zinc, and antimony.

Pot Safety Valve.—A lift valve of annular section, with a central conical recess in which a conical projection on the lever fits, and which slides within wings or horns standing up from the seating. The valve is in a condition of unstable equilibrium, and is therefore not liable to stick.

Pound.—A measure of weight equal to 16 ounces. The pound avoirdupois equals 7,000 grains; the pound troy, 5,760 grains. (The old English pound was the weight of 7,680 grains of well dried wheat from the middle of the ear.) A pound = ·45359 kilogram. The pound avoirdupois is the English unit of mass, and is the mass of a piece of platinum which is preserved in the Exchequer Offices.

Poundal.—The name given to the unit of force—that force which, acting for a second, will give to 1 lb. of matter a velocity of 1 foot per second. The corresponding unit in the metric system is the **Dyne.**

Pouring Basin.—The basin into which molten metal is poured to pass thence into the ingate and runners. It is of a simple cup shape, or a regular concave in the smallest moulds, but in the larger it is made of a double cup section, one being higher than the other, the former containing the ingate. The metal is poured into the lower section of the basin first, and overflows into the higher section, and then begins to enter the ingate, the reason being as follows:—When a big ladle of metal is being emptied into the basin, a few moments are occupied in making adjustments of the lip of the ladle, during which period small quantities of metal drip into the basin. If these fell into the ingate they would form cold shots. But by the time the deeper portion of the basin is filling up, the adjustments are made, and a steady stream of metal is overflowing into the ingate. The basin also affords a ready means

of skimming back any scum which floats on the metal before it can pass into the ingate.

Pouring basins are rammed in green sand within iron rings, in the smaller sizes; or in small moulding boxes, in the larger sizes. The boxes may be square, oblong, or round. The sand is rammed and worked by hand into the required shape.

Pouring Gate.—The ingate, or entrance gate to a mould, to distinguish it from the secondary gates or *runners*, which enter the mould.

Power.—The equivalent of work. The effect of the exercise of force or pressure. It is measured by mechanical units. Mechanical advantage. Used also as a prefix, or affix:—Power plants, power house, hand power, steam, hydraulic, or pneumatic power, animal power, horse power.

Power Gas.—Any combustible gas may broadly be designated as a power gas. Internal combustion engines were first driven by the ordinary retort coal gas as used for house and street illumination, and such gas, with its calorific capacity of 600 to 800 B.Th.U. per cubic foot, was very suitable for use in the small engines which alone were made in the early days of the gas engine industry. But town's gas had its disadvantages and its limitations. It was purified at considerable expense for indoor combustion, and was therefore an expensive fuel to use even in small engines, and this fact soon showed prominently when gas engines grew larger and ran more continuously on regular factory work. Then, again, town's gas was very rich in hydrogen or its compounds, and this rendered it very easily ignitible under very moderate degrees of compression. Pre-ignitions were liable to occur, and these were apt to be dangerous except with small engines. The degree of compression had consequently to be kept very moderate. But since economy is best secured with a high rate of compression, it followed that the rich gas could not be employed to the best advantage As the gas engine grew in size, the gas producer was brought into use; this converted coke or anthracite coal into carbonic oxide gas for power purposes, and, in order to make the fullest use of the heat generated by this production of carbonic oxide, it became customary to blow a certain proportion of steam through the hot fuel with the air supply. The formula for the production of carbonic oxide from coke or pure carbon with atmospheric air is approximately as follows: $(O+4N)+C=CO+4N$, the N being the unavoidable nitrogen of the atmosphere, which remains, of course, in the product and greatly dilutes it, reducing its calorific capacity, and rendering the gas very safe for high compression. But when using steam, the reaction in the producer is as follows:—

$$(O+4N)+H_2O+2C=2CO+H_2+4N.$$

Here the same amount of air suffices to produce twice as much carbonic oxide. There is also an equal volume of pure hydrogen, and in place of two volumes of CO and four of diluent nitrogen, the steamed producer gives four volumes of CO and two volumes of hydrogen, or six volumes in all of combustible gas, and still only four volumes of nitrogen. The relative dilution of nitrogen is now only two to three in place of two to one, and the resulting gas is much more calorific.

The steam is split up by the heat of formation of the CO, and the hydrogen is set free, while the oxygen takes up carbon from the red-hot coke, and produces more CO. The amount of steam that can thus be fed into a producer is limited. If too much is employed, the producer will be cooled and ultimately extinguished altogether. The actions above outlined are never carried out perfectly. Some of the carbon becomes completely burned to dioxide or CO_2. This represents so much absolute waste. Air may pass unchanged through the fuel in the producer. This will account for the presence of oxygen in the gas and in itself cannot be called a waste.

The large amount of hydrogen is, of course, apt to set up pre-ignition, and must be guarded against by carefully moderating the compression, thus limiting the economy to be secured. Hence the adhesion of some engineers to the use of a power gas of not over 120 B.Th.U. capacity per cubic foot, one fairly free from hydrogen down to about 5 or at most 8 per cent. Blast furnace gas appears to be an almost ideal power gas, for it has a calorific capacity of only some 100 B.Th.U. per cubic foot, and it is low

in hydrogen. It will therefore stand a high degree of compression with safety, and yet it will ignite with regularity and certainty. Some hydrogen is regarded with favour, because the presence of hydrogen assists the propagation of flame throughout the mass of a charge of gas in a cylinder.

The following analyses of various power gases are given by Bryan Donkin:—

Name of Gas.	CmHn.	CH_4.	CO.	H.	$CO_2 + N$.
Lighting gas - -	3·5 to 7	30 to 40	5 to 10	35 to 50	Remainder.
Coke oven gas - -	1·5 to 3	25 to 35	5 to 10	50 to 55	,,
Blast furnace gas -	...	0 to 1	20 to 28	3	,,
Producer gas - -	...	1 to 2·5	16 to 28	10 to 20	,,
Mond gas - - -	...	1 to 3·5	3 to 16	25 to 30	,,

The calorific capacities in the order named are 450 to 560; 340 to 560; 84 to 110; 124 to 146; and 136 to 146 B.Th.U. per cubic foot. It is obvious that with a producer worked without steam the analysis will resemble that of blast furnace gas, and it is to such a gas, with little hydrogen and safe at high compression for use in big engines, that the term power gas is perhaps most usually considered applicable.

Water gas is made by passing steam alone through a mass of incandescent fuel, rendered incandescent by passing air through it and running the carbon dioxide to waste. Water gas is thus produced by an alternating process of air and steam blast, the steam produced gas alone being saved, and being composed all of H and CO, or $H_2O + C = H_2 + CO$. Air gas is produced when air alone is passed through a deep bed of fuel, and the result sought for is CO and N. Between these extremes there are any number of gases possible under the name of semi-water gas, the process usually being continuous and not more steam being employed than can be dealt with by the surplus heat of the producer. An ideal air gas contains 34·7 per cent. of carbonic oxide and 65·3 per cent. of nitrogen. As made in practice there will be about 32·5 per cent. of CO, 1 per cent. of hydrogen, and 1·5 per cent. of CO_2, very little steam being used. Much of the power gas in common use is made in what are termed suction producers, the action of which differs nothing in principle from that of the fan blown producer.

The latest type of gas producer resembles the blast furnace in that it is supplied with a certain proportion of limestone with the fuel, this limestone serving as a flux for the clinker of the fuel, which is thus enabled to be discharged liquid from the producer, thus saving the labour of clinkering. But in all the many modifications of operation all producers work on the same general lines and produce either air gas, water gas, or some intermediate variety. There are still those who will not agree that a gas rich in hydrogen will explode more readily than other less hydrogenous mixtures, but the general consensus of opinion is in favour of limiting compression where hydrogen is present in considerable percentage. Since compression is at the basis of economical working, it is regarded by some experts to be necessary that future developments should embody that system of working gas engines which introduces the gas in a state of high compression itself into an already compressed charge of air at the exact time when combustion is wanted to take place. This is already done in the Diesel and in the Johnston oil engines, and ought to be done with the gas engine, for it is the best assurance of safe working. It enables the gaseous charge to be burned gradually instead of being violently exploded. When this has been carried out to a successful issue, the range of composition of power gas can be safely extended to any percentage of hydrogen that may be found desirable for economy of producer working. Pending this, however, power gas must consist essentially of carbonic oxide with its unavoid-

Fig. 143.—Portable Electric Drilling Machines. (Emil Capitaine & Co.)

Fig. 144.—Portable Electric Drilling Machine. (Campbell & Isherwood.)

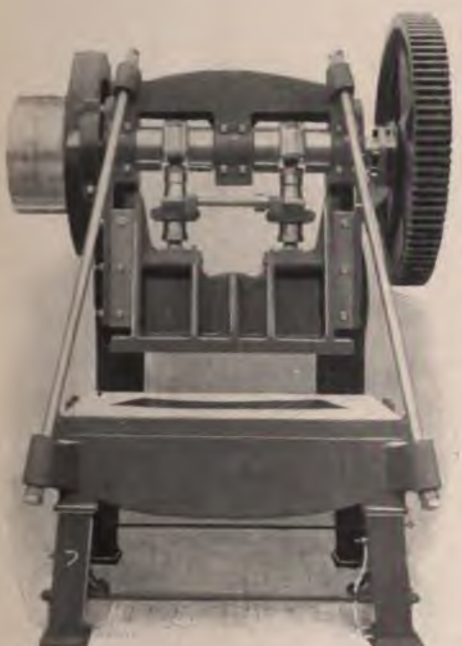


Fig. 148.—Power Press. (J. Rhodes & Sons, Ltd.)

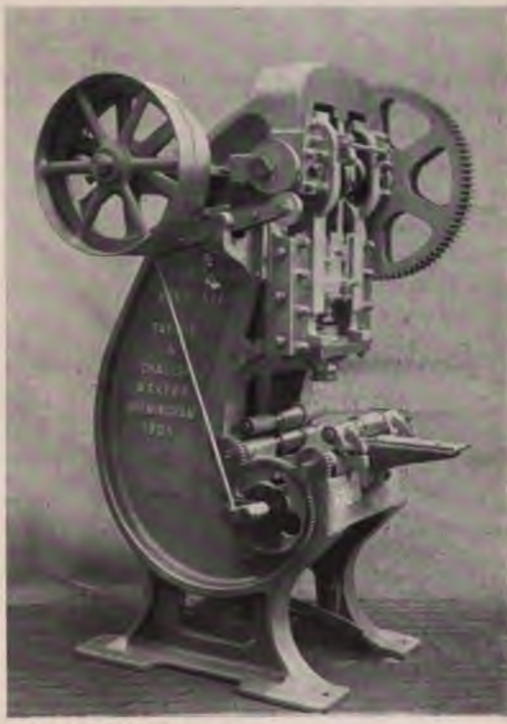


Fig. 149.—Self-Feeding Power Press. (Taylor & Challen, Ltd.)

To face page 130.

able diluents. *See* **Blast Furnace Gas, Fuels, Gas Engine.**

Power Hammers.—These are used for the larger class of engineers' forgings, and coppersmithing, and vary in type and dimensions with requirements. Many are belt-driven. *See* **Pneumatic Planishing Hammers, Pneumatic, Spring,** and **Steam Hammers.**

Power Press.—A press in which sheet-metal articles are blanked, or cut out, stamped or drawn into shape, &c. The movement is derived from a revolving shaft, operating cam, or eccentric, or toggle actions, which impart an up and down motion to a ram sliding between guides, above a table or bed on which the work is placed in suitable dies. The ram carries punches or dies, and by the combined action of these and those on the table the work is accomplished. A clutch mechanism is incorporated, by which the connection between the driving pulley and the cam shaft may be broken, to let the shaft stop, and keep the ram at its highest position until a stroke is required. A treadle is depressed, and the ram descends, then rises, and dwells at the top position. The reason for this is to allow the operator time to place a fresh article in the dies, without risk of injury to the hands. In cases where operations can be carried on continuously, such as in punching blanks from a long strip or roll, the machine runs without stopping, and the attendant has only to see that sufficient material is supplied. Rollers are usually employed for feeding, and they are driven by a crank-disc or cam on the end of the main cam shaft, so that the relative motions are correctly timed.

The larger presses are powerfully geared, to obtain sufficient pressure, amounting to as much as 1,000 tons in some cases.

A heavy type of press, employed for blanking, perforating, embossing, &c., is shown in Fig. 148, Plate XI. It has a $2\frac{1}{2}$-in. stroke, and the bedplate measures 54 in. by $35\frac{1}{2}$ in. The ram is actuated by two couplings from the eccentric shaft, a simultaneous adjustment of the screws of the couplings being effected by worm gear, to alter the height of the ram. The driving is effected from the fast and loose pulleys at the rear left-hand, connected through spur gear to the eccentric shaft; a pressure of 150 tons can be exerted. The bolts which tie the body casting to the bed are splayed out to avoid interference with sheets placed in the dies.

A press fitted with automatic feed rollers for ribbon metal is illustrated in Fig. 149, Plate XI. It is constructed for combined blanking or cutting, and cupping or drawing, there being an inner ram working with an outer slide. The height of this inner ram is adjustable by a screwed coupling, by which the relative positions of the cutting and the drawing dies are modified. The automatic feed given to the rollers seen on the bedplate is effected by spur gears worked from a connecting rod rocked by a lever actuated by a cam on the eccentric shaft. At each stroke of the rams, therefore, the feed rolls are given a partial turn which feeds the sheet forward under the dies.

Power Transmission in Factories.—The choice of the method of transmission of power in a works lies between belts and electric motors. A compromise is effected by driving sectional lengths of shaft by motor, thence driving by belts to the machines. This is rendered necessary by the fact that existing machines are mostly adapted for belt drives only. Main belts are thus done away with, but that is all. The use of main belts and main rope drives is lessening in the modern factory. The electric conductor is taking their place, and motor-driven machines. The agents of transmission, as shafting, bearings, and so on, are, thanks to the use of steel shafting, swivel bearings, and self-lubricating arrangements, less wasteful of power than of old. Roller bearings have been introduced into factories for shaft bearings. The enormous amount of belting and pulleys required in a large establishment gives rise to problems of great importance that affect not only the general arrangements or lay of the shafting, but also the questions of the new machinery which will be required from time to time. Alternative arrangements of shafting have to be considered in planning a shop. The use of an overhead traveller prevents running the main shaft down the centre of the roof, unless it can be kept well above the traveller, which is not often possible.

The two best methods of driving when circumstances permit, and by which the traveller is avoided, are these:—In a shop which is not flanked by side bays, the line shafts are placed as high up as possible, just under the traveller girders, running between the columns, when the construction of the latter is of the open kind. The drive from thence to the countershafts is then nearly vertical. In this case, grids or plates bolted between the columns receive the bearings for the counters. The traveller girders, or the upper portion of the columns receive the bearings for the line shafting, or the motors if the electrical drive is adopted. The objection to this method is the vertical drive, and the shortness of the belt coming from the line shafts to the counters. It is not good practice, but in the class of shop named there is no alternative.

When a main shop with a traveller is flanked by side bays without travellers, then the line shaft is often carried in the latter, driving to counters at the sides of the main bay. The same line shaft also may drive light machines in the side bay. The foregoing matters, and those which are related thereto, have to be thought out and settled before the details of the buildings are fixed. The problems of smithy and boiler shop are akin to these, and need not be detailed. In some cases a plan is adopted which is open to the objection of occupying floor space. The countershafts and bearings are carried on tall standards bolted to the floor, and high enough to give a reasonable length of belt drive to the machines. This is a design which is only adapted to a few light machines stuck down in the middle of a shop, away from a proper support for countershafts. Underground shafting is employed in a good many wood-working machine-tool shops.

In laying out a machine shop a difficulty lies in the fact that the equipment of machines cannot be foreseen for a long term of years; that though laid out with good judgment in the first place, a few years may suffice to effect profound changes in the methods of doing work, without even supposing any alteration in the class of work done. It is therefore necessary to make arrangements that will permit of the laying down of new machines, and if need be, of making rearrangements in the location of existing machines. This involves alterations of the countershafts, and to effect these readily is the object of many devices in use. The old-fashioned method of boring fresh bolt holes in timber beams as often as countershaft bearings require to have their positions altered is a barbarous one, that should no longer be tolerated in a works. There are several devices which permit of such alterations in position without boring holes. Besides this, timber is not the best material to use, notwithstanding that it is retained in large numbers of establishments. There is always a slight risk of fire occurring if dust is allowed to accumulate on timber beams. Timber is liable to warp, and throw bearings out of truth, and it lacks rigidity. The best method of fixing the bearings of countershafts is to bolt grids between the main columns, and these are therefore largely used, cast iron being generally employed in preference to mild steel, because stiffer and better qualified to resist the vibrations set up by the pull of belting. The forms used vary from simple chequer work or open plates to boxed built-up frames. A single ribbed, chequer-work plate may be used, but a better design is the boxed one. This plate serves two adjacent bays, so that bearings can be bolted to each vertical face, and also to the bottom one. The construction is that of four chequered plates cast in lengths of about 6 ft., bolted together and to the main columns.

The nature of the provision made for electric driving depends on the system selected. The sectional system seems the best to adopt excepting in the case of very heavy machines, which should each have its individual motor. The advantage lies in the greater economy of large motors over small. In the machine shop of the English Electric Manufacturing Co., Ltd., of Preston, the 800 ft. of line shaft that runs down the centre of the machine shop is divided into eight sectional lengths, so arranged that each can be driven by its own motor, or the whole by one or more motors. All the machine tools, some of the larger ones excepted, are driven from this one line shaft in eight motor-driven sections. In the Arc Works of Crompton & Co., Ltd., of Chelmsford, the

sectional and the individual systems are both employed. There are three sectional lines of shafting, each driven by its own motor, driving miscellaneous groups of tools. But all the heavy and medium heavy tools are driven each by its own motor of a type designed by the Company, and suspended from the longitudinal girders that carry the travelling cranes. These motors range from one to six horse power, and the speeds of their countershafts range from 100 to 250 revolutions per minute, reduction being by means of raw hide pinions working into cut gears.

Power Transmission Lines.—May be lengths of electrical conductors, either as underground cables (*see* **Electric Cables**) or overhead conductor lines; usually the latter are thus called.

Transmission lines are usually constructed of bare copper wires or rods carried upon insulated supports attached to wood or steel poles fixed in the ground. There are not many heavy transmissions as yet in this country, of any great length, although numerous examples of short private power lines have been erected where scattered works are supplied with power from a central station. The best example is probably that of the North Wales Power Co. recently constructed for transmitting three-phase current a considerable distance. On the Continent and in Canada and the United States there are many long lines carrying thousands of horse power, in some cases several hundred miles at pressures up to and over 60,000 volts.

The conductors are usually of copper, although phosphor bronze and other similar alloys have been in some cases tried. Aluminium has also been experimented with, but copper appears to have the best qualities for this work. The insulation is, of course, most important, and the transmission line has been awaiting the development of insulators suitable for the very high pressures necessary for economical transmission over long distances.

Insulators have, however, recently been much improved, so that transmission lines are now rapidly increasing in size and length in places where centralisation of plant to serve large areas is an advantage.

Some types of the insulators used will be found illustrated under **Insulators**.

Pre-admission.—The introduction of steam to a cylinder to act against the piston immediately before the termination of its stroke. This is regulated by the lead of the valve.

Precipitate.—A precipitate is a solid substance thrown down in a liquid owing to the decomposition of the latter by the action of a chemical agent, a gas, or sometimes the action of the air. The precipitate may either have been formed by chemical action or have been held in solution. Precipitation is resorted to either to purify solutions, or in chemical analysis. The addition of a suitable reagent to a solution gives a characteristic precipitate. Thus, solutions of ferric salts yield a brown precipitate with ammonia; solutions of lead salts yield white precipitates with dilute H_2SO_4, or HCl, and a yellow precipitate in potassium iodide; sulphuretted hydrogen throws down a black precipitate from cupric compounds, and so on.

Premium Systems, or **Bonus Systems.**—Designed to avoid the evils both of day work and piece work. The fundamental idea is that the workman in any case receives his day wages, but extra output is rewarded by a definite share of the value of the additional output. In this way the cost of the job is reduced to the employer, while the workman receives more pay. Statistics prove that the average time taken by machinists working under this system has been reduced by from 20 to 35 per cent., in some cases more, by comparison with the time occupied when day work was the practice.

An essential to the successful working of this system, as in piece work, is, that prices once fixed should not be altered, except when the conditions imposed by machines, jigs, and other aids are changed. In fact, cases have occurred of firms having miscalculated prices, and continued to allow the men to earn high premiums rather than break faith, and destroy confidence. Out of the premium system has arisen the need for "rate fixers." These are men whose sole duty consists in noting the time occupied on each individual job in the shop, and from these data fixing the rates for the men. This is done in order to relieve the foreman of that particular duty, and to provide

an impartial assessor between employers and men. It is a fact that few workmen are able to estimate the time which a job should occupy, even though it is done on a machine which they are constantly operating. And there are many leakages and little losses which tend to disappear under a system which puts a premium on economy. Men on day work may honestly endeavour to render a fair return for wages, but the same men under the inducements of the premium system do in fact turn out considerably more.

The premium system is now about twenty years old, having been first introduced in America. The Halsey system is that most in use there. In England the Rowan, and the Weir are adopted. The differences are those of proportionate division of the money saved. In the Halsey system 30 per cent. was given to the workman, in the Weir one-half the time, in the Rowan extra wages payment in direct proportion to the time saved, so that if a man saved ten hours on a job he would receive ten hours' extra pay. It matters little what rate is fixed, though to encourage the workmen it should be high. The essentials are the stability of time wages, the inducement to earn extra, and the separation of jobs, so that a loss on one job will not have to be made good from another.

Pre-release.—Opening the end of a cylinder to exhaust immediately before the termination of the piston stroke, to avoid the evil of excessive back pressure.

Press.—*See* Specific heads.

Presses.—*See also* **Baling Press.** Presses are used for compressing agricultural and other products into bales. For the heaviest work hydraulic presses are used, but there are a great many varieties of press worked by hand, or by horse power, or by a belt from an engine. They are used chiefly for baling hay and straw. The hand-power presses are generally worked by a lever and toggles, or in some cases by screw power. The mechanism is arranged so that with uniform power at the lever the ram or platen moves quickly at first, and slowly and with greater power at the conclusion. A pawl and ratchet prevents slipping, and means are provided for exposing the parts of the bale for tying before releasing. The horse-power presses are generally worked by a horse walking in a circle. They are arranged so that the power expended is equalised throughout the operation. The power-driven presses usually have a quick release whereby the ram is drawn back in about one-quarter of the time it occupies in moving forward. The speed of the forward movement is varied also, being quick at the commencement of the stroke, when little power is required, and slow at the end, when the maximum power is exerted.

Press Fit, or **Force Fit,** or **Driving Fit.**—A fitting of shaft and bore so tightly that it has to be effected by hydraulic, or screw pressure. *See* **Limit Gauge, Limits.**

Pressure.—The force exerted by one body on another. It may or may not produce motion; in the first case it is dynamic, in the second static. The phenomena of pressures are constantly in evidence in engineers' work, in solids, in liquids, and gases, the leading facts of which are stated under specific heads. Pressures in rigid bodies produce stresses and strains; liquids, being practically incompressible, transmit pressures equally in all directions, and in direct proportion to area. In gases, pressure generates heat, and therefore pressures and temperatures are related, a fact utilised in all heat engines. Reuleaux has applied the term pressure organs to distinguish a group of machine elements from the tension organs. It is a convenient classification, including as it does all fluids, whether liquids or gases, the particles of which can be separated readily, but which will endure compression, the utilisation of which occurs in the transmission of pressures, and of movements under pressure. It includes all the mechanisms in which steam, air, and water are used, whether statically, or dynamically.

The increase in pressures in steam boilers has had a most marked influence in the practice of the boiler shop, and in the development of powerful machines, and has been a factor in the growth of the water-tube boiler. It has also revolutionised the manufacture of steam pipes. The high pressures used in hydraulic pumps, accumulators, and presses have exercised no less influence on the practice of the foundries dealing with this class of work. Not only mass, but judicious distribution of metal, and

ls of pouring, and of coring, and staying re affected.

highest pressures employed are those re- in scientific experiments in gases. Sir ick Abel, and Sir Andrew Noble in their hes on the gases from fired gun-powder rdite, obtained in closed steel cylinders res as great as 95 tons to the square nd temperatures as high as 4,000° Cent. eriments on the liquefaction and solidifica- gases, high pressures are combined with g mixtures. *See* **Atmosphere, Baro-, Centre of Pressure, Cylinders—gth of, Dam, Gases, Hydraulics, ostatics, Retaining Walls,** and other subjects.

ssure Blower.—Distinguishes the e blower from the exhauster and from ı. *See* **Blower.**

ssure—Centre of.—*See* **Centre of ure.**

ssure Filter.—A type of feed-water employed for removing the grease from ater through a filtering medium. The dy filter, Fig. 150, is shown in , from which its construction will be The course of the water is indi- by the arrows entering at the right- nlet, passing through a valve con- by the hand-wheel, thence through iner into the filtering portion, consists of cocoanut fibre upon gun-metal The course then taken is down through tlet valve and out through the left-hand e. The cock in the lid is an air-outlet nd the one placed above the feed-inlet s for steam cleaning.

difference in the pressure type filter e suction type, is that the first is situ- etween the feed pump and the boilers, he second is placed before the feed pump, e water is therefore drawn through, of being forced. The construction of o patterns differs but slightly.

ssure Gauges.—These are divisible o main types; the mercurial, or those depend for their action on the pressure atmosphere, and the metallic or steel ype, in which the elasticity of metals is l.

Mercurial Gauges.—These have long been obsolete, having been unsuitable for high pressures, besides not being of compact design. The principle is, that the pressure of the steam acting on a column of mercury in one leg of a U tube forces up the mercury in the other leg, and a float on the surface of that is made to give a reading on a scale corresponding with the pressure. Such a gauge could only be used for very low pressures. Another type,

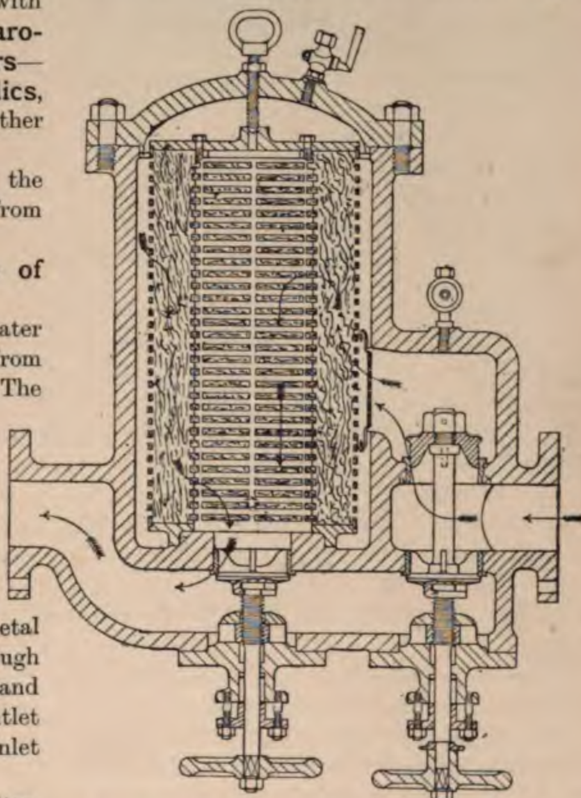


Fig. 150.—Pressure Filter. (John Kirkaldy, Ltd.)

therefore, has been used in which a closed tube receives the pressure, the column of mercury therein being thrust up against the counter-pressure of a column of air above it. The pressure of the air will, therefore, be inversely in proportion to its compression. But such gauges have gradually gone out of use, since the metallic types have been invented and perfected. In another form of this gauge, mercury is used, for testing spring gauges, to be noted presently.

Spring Gauges.—The first pressure gauge was invented by the late Mr Sydney Smith in 1847, and appears to have been invented independently by Herr Schäffer of Magdeburg in 1849. Mr Smith's design differed from the present Bourdon gauge. A circular steel spring was connected by a piston rod to a piston, at the top of which, fitted in a flanged recess, was an indiarubber diaphragm. A straight rack connected to the spring moved a pinion, on the axis of which the registering pointer was fixed.

The instrument was termed a *steam indicator*, and was first fixed at the Tapton Collieries, in October 1847, under the instructions of George Stephenson. Orders soon came in, and hundreds of them were fitted in a short time.

The Bourdon Gauge.—The first idea of using metallic substances is due to a Frenchman named Vidi. The Bourdon tube was first invented in 1845, by Herr Schmitz, a German engineer. Bourdon, in 1850, patented the tube, which patent was contested by Vidi in 1859. It is said that the first idea of the tube arose in consequence of M. Bourdon, when trying to force out a worm pipe of a still which had become flattened, observing that the tube tended to uncoil.

The general construction of the Bourdon pressure gauge is as follows, Fig. 151: — The mechanism is contained in an outer casing, the brass *case* A, turned and polished, which encloses the *works* or *movement* of the dial. The case and the movement are carried on a piece termed the *base plate*, or *shoe*, B, which is screwed into the siphon pipe, so that there is perfect freedom and independence of the works, in the event of pressure or damage to the outer case. To the base is attached one end of the tube C. The other end is linked to the toothed quadrant D, which transmits the motion of the tube to the pointer E.

The action of the gauge depends on the fact that if a tube of elliptical section is bent into a scroll, with the larger axis of the ellipse coincident with that of the scroll the tube will, under the influence of internal pressure, open out to a larger diameter. As the end which is attached to the base piece cannot move, the opposite end does, and this being fastened by a stout connecting link to the tail of the toothed quadrant, the latter moves in a radius, and its teeth engaging with those of the pinion turn the latter. Obviously the tube is the most important element. Steel, or gun-metal is used, the introduction of steel being due to Messrs Schäffer & Budenberg. Holes are bored in solid bar, after which the flattening to the elliptical shape is done between dies, and the bending to the spiral in other dies, and the tube is then hardened. Another way is to roll sheet metal into strips and solder with silver solder. Or the tubes can be solid-drawn to the elliptical

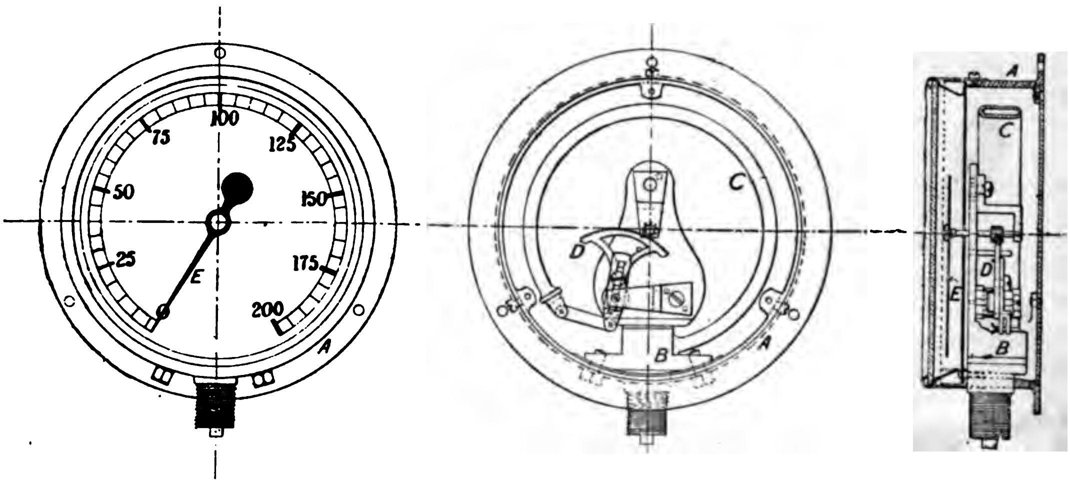


Fig. 151.—Bourdon Gauge. (Dewrance & Co.)

at once. Bourdon tubes are sometimes of common brass brazed tubes, flattened ellipse, filled with lead, and bent. Or ly hard brass tubes are used. Generally azing is on the inside curvature, because subjected there to compression. The on to brazed tubes is that the metals different have different elasticities, and variations in the pressure results. Seam-onze tubes are used, and Messrs Dewrance make these drawn at once to the circular by which the presence of puckers on the al curve is avoided. Above 3,000 lb. re the firm uses tubes of steel.

he manufacture of gauges, templets and e used, so that the fittings are inter-able. But each individual gauge in the akes has the positions of the pointer for at pressures marked for that gauge only, ect calibration with standard gauges. latter are calibrated at short intervals a tall mercury column. The highest y column in England is that at the ipal Technical College, Manchester. It metres high. There are taller columns , used for experimental purposes; the is one at Butte-aux-Cailles, of 500 metres, atmospheres. There is one on the Eiffel of 300 metres in height, or 400 atmos-pressure. Messrs Schäffer & Budenberg epeatedly calibrated their dead weight lic testing machine by this column. For ordinary gauges, Messrs Schäffer & berg supply columns which can be fixed wall, inside or outside a building. They n scale from 15 to 300 lb. per square inch. ter requires a height of 52 ft.

ng Gauges.—A steam gauge must be veral inches above the highest water level boiler. It should stand away from the where it will not become heated. It must ched with a bent or siphon tube which re-ater. Also a stop-cock should be fitted n the gauge and the boiler, to shut off when examination is necessary. The ould be opened and closed slowly to avoid to the works. A pressure gauge is de-for the tube to be amply within the f its elasticity. But it is not advisable a gauge to more than half its maximum working pressure. The pointer will then be in a vertical position for the normal working pressure.

Hydraulic Gauges.—These are used for all kinds of hydraulic machinery, presses, &c., and in range for pressures from half a ton to 34 tons per square inch.

Self-Registering Gauges.—These provide for a diagram of variations in pressure through a period of twelve, or of twenty-four hours. There are two types, the drum, and the circular disc. Connection is made to a pen or pencil by suitable levers. The drum, or the disc rotate once during the period selected, namely twelve, or twenty-four hours, and the diagram paper has to be renewed after one revolution.

Many boiler explosions have occurred through defective gauges, in which bad workmanship has been the most contributory cause. Every fitting should be free, without being too easy. Whatever causes risk of sticking is a source of danger. Hence care in manufacture is of first importance, and the best fitting is essential.

Prime Numbers.—A prime number is one which cannot be divided without remainder by any number except itself and unity; *e.g.*, 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97. These are all the prime numbers under 100; the rest are composite numbers.

Numbers are prime to one another when there is no number but unity which will divide both of them exactly; *e.g.*, 14 and 27. (But though these are prime to one another they are not themselves prime numbers.)

Priming, or **Foaming**.—The intermixture of particles of water with the steam in the upper parts of boilers, passing into the steam pipes and cylinders. *See* **Anti-Priming Pipe**. Priming a lift pump is the equivalent of *fetching* the water, by pouring a quantity on the bucket to enable a vacuum to be produced below. Also the expulsion of the air from the water space of a force pump by opening the pet cock.

Print, or **Core Print**.—A part of a pattern which leaves an impression in the mould to receive the end of a core. It keeps the core in its correct position, and in most cases is necessary also for the purpose of steadying and supporting it. In the case of a core which rests in

the bottom of the mould, the impression left by the print merely guides it into the correct position and prevents it from moving sideways; and in cases where the core has a small base compared with its height, it assists in keeping it vertical. In cores which do not rest on the bottom but have to be supported in the sides of the mould, the print impression both indicates

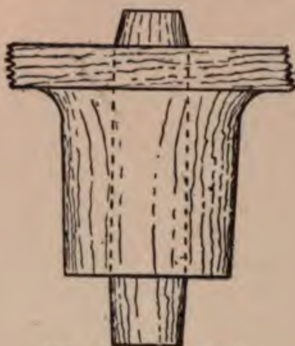


Fig. 152.—Core Prints.

the position and affords the necessary support for the end of the core. The shape and size of a print, therefore, must conform to the character of the core it is intended for; and the amount to which the print projects from the surface of the pattern depends on the amount of support the core requires.

The form of print most commonly used is a cylindrical one, to suit the end of a core of that shape, Fig. 152. In their small sizes these prints are generally about the same length as their diameter, but as diameters increase lengths are reduced. A print, 1 in. in diameter, for instance, would for most circumstances be well proportioned if it was 1 in. long; but a print 6 in. diameter would often not need to be more than 1 in. long; while prints of 2 in. or 3 in. diameter would seldom be more than 2 in. long. The steadiness of a core resting in the bottom of a mould depends as much on its length as on the diameter of its base. A core 3 in. diameter, for instance, would stand steadily in a very shallow print impression if its total length was only 2 or 3 in.; but if it was 12 in. it would not be wise to rely on the bottom print alone, no matter how deep it was made. In such a case two prints would be used, Fig. 152; one to form an impression in the bottom of the mould, and another in the top; so that the core would be secured at both ends. In horizontal cores, support at both ends is essential, unless the cores are very short indeed; and the larger the core the greater must the print length be.

When both top and bottom prints are used, the top print is usually made shorter than the bottom, and is given a great deal of taper, as in Fig. 152. This taper serves the double purpose of facilitating the lifting of the top sand from the pattern, and enabling the top end of the core, which is tapered to correspond, to easily find its way into the impression when the mould is being closed. Bottom prints are given a slight amount of taper to enable them to leave the sand easily.

Parallel prints on the sides or ends of a pattern sometimes cause complications in moulding that do not exist in the case of prints on the bottom or top. Except in the few cases where for special reasons they are skewered on loosely and drawn after the pattern, there must always be a joint in the mould coinciding with the upper surface of the print, so that the latter can lift with the pattern without injury to portions of the mould above it. This is done either by jointing the pattern through the prints, as in cylinders, pipes, Fig. 153, and many other

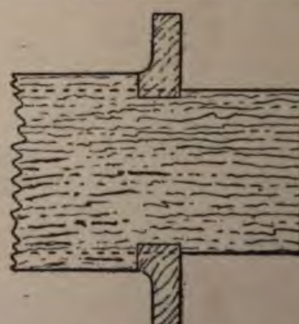


Fig. 153.—Core Print.

cases, where, even if there were no prints, the pattern itself would have to be jointed; or by jointing down to the upper surface of the print, as is often done in small work, or work of very irregular outline; or by modifying the form of the print to make its upper surface coincide with the joint of the mould. This latter method is generally adopted when it is not convenient

to joint the pattern through the print. The method of jointing down to the upper surface of the print is only practicable under favourable conditions. It is done in the mould, the pattern itself being solid. The modification of the form of the print is generally best and does not prevent it from serving its purpose equally well. It consists in making the lower portion

Fig. 154.—Pocket or Drop Prints.

of the print, which forms the bed for the core, of the correct shape, but ignoring the core shape in the upper part and simply tapering the body up to an increased size at the joint of the mould, Fig. 154. This leaves a space to be filled in with sand after the core is in place. In some cases the end of the core itself is made similar to the print and fills the space. This modified form of print used on the sides of patterns is called a *pocket* print, or *tail* print, or *drop* print. It is employed most frequently for cylindrical cores, but is applicable to cores of all shapes that do not come up to the joint of the mould.

The size and shape of a print, though usually similar to the opening at the surface of the casting, is not necessarily so. All that is necessary is that it should fit the portion of the core which projects beyond the casting. There are occasionally reasons why the cored hole and the print should not coincide in size or shape, and in such cases the necessary difference is made in the core.

In cored work it is often desirable, and is the uniform practice in some shops, to distinguish cores from metal on the pattern faces. This is done by painting or varnishing either the cored parts, or the metal black. Sometimes one, sometimes the other is so painted or varnished. It does not matter which, so long as a uniform practice is adopted. The adoption of such a system prevents mistakes in the foundry, and saves time otherwise spent in sending for the pattern-maker and asking for information as to location of cores and of metal.

Where this is not done, the practice should be adopted of distinguishing core prints from metal by colour. Usually the metal is yellow, and the prints black. The principle may be extended to distinguish patterns for iron from those for gun-metal by the simple device of painting the latter patterns black, and their core prints yellow, as is done in some shops. It is careless practice to make no distinction between core prints and metal, which has often resulted in metal being cast for core prints, and holes being cored where there should have been metal.

Prism.—A prism is a solid whose ends are plane figures which are parallel, equal, and similar, and the sides are parallelograms. A right prism is one having sides perpendicular to its ends, as distinguished from an oblique prism with sides inclined to the ends. The prism is named after the shape of the ends, as triangular, square, pentagonal, &c. The area of a prism is found by multiplying the area of

Fig. 155.—Prismoid.

the base by the height. The mensuration of prisms and other solids is dealt with under their respective titles.

Prismoid.—A prismoid, Fig. 155, is a solid whose faces are trapezoids and whose ends are two parallel plane rectilineal figures of the same number of sides. The volume

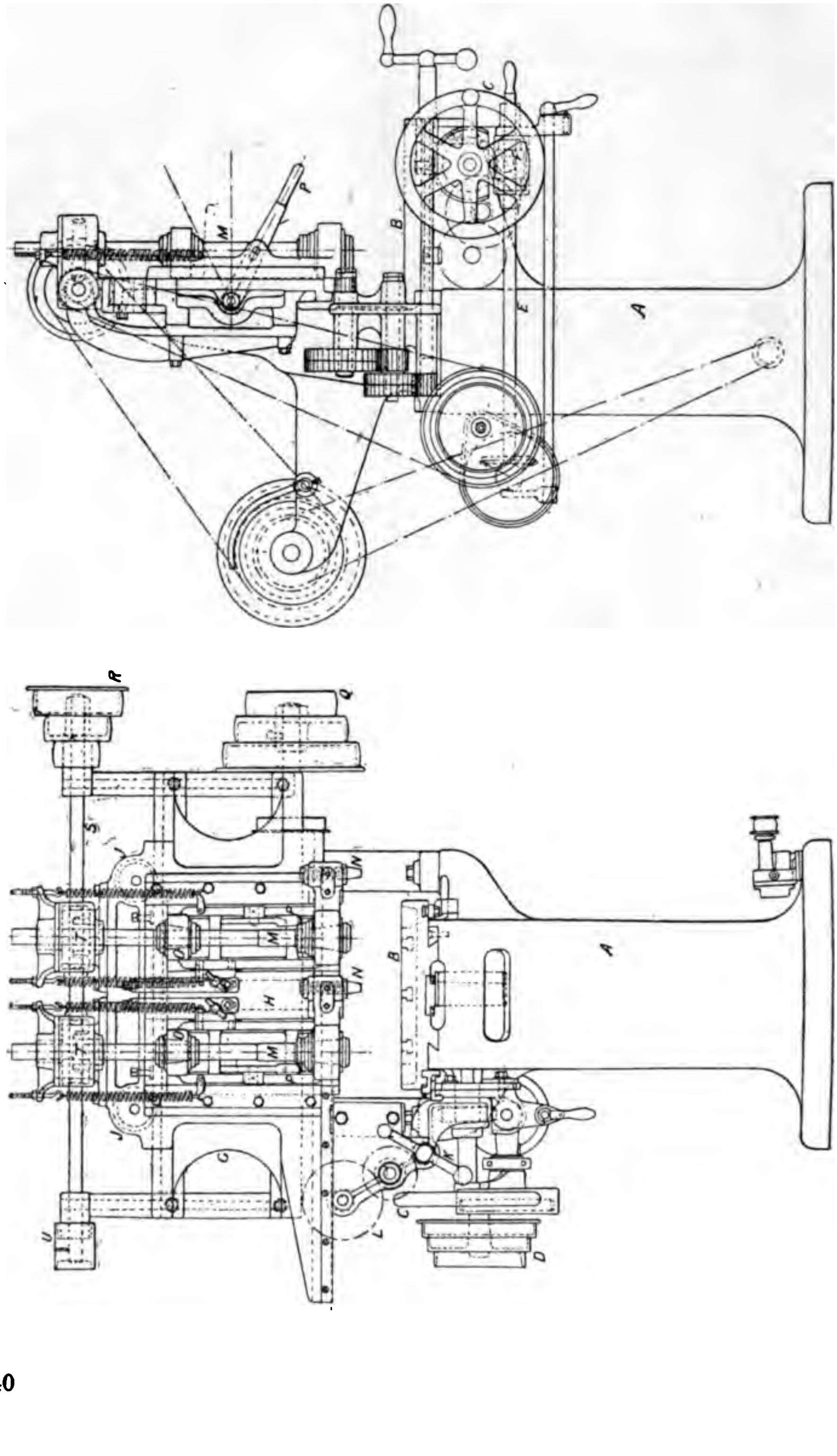


Fig. 158.—Profiling Machine.

noid may be calculated by the

$$. = \text{Height} \times \frac{AB + ab + 4Mm}{6}.$$

f base; *ab* is area of other parallel the area of a middle cross section as 155).

1.—A question proposed for solution. rom a theorem in that the latter truth of a proposition to be proved. opositions consist of problems and

s of Combustion.—These are $_2$ (carbon dioxide), CO (carbonic H_2O (water). d other waste blast furnace gases , hydrogen, and hydrocarbons— d for heating purposes, and for e **Gas Engine**. They require , which is done in three stages a g, a wet cleaning, and for power cleaning by means of fans. *See* eous **Fuel**, and **Regenerative** .

Governor. — *See* **Spring** s.

Milling.—A class of milling which to the production of curved and utlines. Profiles are milled in either rs. A form cutter may be used, cor- in outline to the desired shape; or, *copy* may be employed to guide a a definite path to mill the shape. ers do not differ in construction from raight **Milling Cutters**, excepting roduction of curves. Backing-off is always done, in order to impart the teeth, and to enable the profile to ed, unaffected by repeated sharpen- the smaller cutters are made in one, practice when considerable lengths, e curves and straight portions are being to build the cutters up of which facilitates manufacture, and is for arranging different profiles. Fig. XII., shows a gang mill combining nd curved sections, for milling con- s, several of which are held in a vice ecial jaws for gripping and locating one-half is milled first, and the links are then turned over, and the other side finished.

The other class of profiling embodies the principle of laying down a steel copy or pattern of the outline to be shaped, and causing a tracer pin to press against it, while longitudinal traverse is given. The pin therefore moves to and fro as it is coerced by the copy, and being fastened in a suitable slide, causes the latter to move similarly. A cutter, held in a spindle in the slide consequently moves exactly like the pin, and will mill the profile of a piece of work laid down parallel to the copy. For convenience, the copy and work are both bolted down to a travelling table, above which the pin and cutter are situated. Fig. 157, Plate XII., shows a plate to be fastened to the table in the machine described below, carrying a copy, and a piece of work, a cycle crank. The roughing, and the finishing cutters are seen to the left, and the tracer pins to the right.

Profiling, Profiling Machine.—Fig. 158 shows a two-spindle profiling machine by Messrs H. W. Ward & Co. The column A, which forms a suds tank, supports the sliding table B, moved by hand-wheel C, operating a rack pinion; or by power, through pulley D, bevel gear, and shaft E, driving a worm gear F, which is tripped automatically by stops on the edge of the table B. The cross-rail G supports the saddle H, running with anti-friction rollers J on the top edge. The tracer pins are kept against their copies by feeding the saddle laterally, through the balanced handle K, and train of gears ending in L, which meshes with a rack on the underside edge of the saddle. Arrangements are made to take up back-lash in the gears by halving them, to reduce negative movement to a negligible amount. The two cutter spindles are marked M, M, and the tracer pins N, N, the latter being fixed in lugs, and provided with adjustments by means of nuts. Each spindle runs in bearings in vertical slides, O, O, adjustable by the handles P, P, and balanced by two coiled springs on each side of the bearing, at the top. The slides can be locked in any position. The drives to the spindles take place through the belt cones Q, R, the first being driven from fast and loose pulleys on the shaft at the rear, forming a self contained counter-

shaft. A shaft S, rotated by R, drives worm gear inside the casings T, T, and the spindles M, M are prolonged and splined to pass up through the boxes. A practice that is largely followed is that of driving by a twist belt, from a long drum in the same position as the shaft of Q, at the back, the belt passing between an opening in the vertical slide and lapping around a small but long pulley on the spindle. Another pulley U at the end of the shaft S drives the cone D. The spindle speeds are 160, 89, and 54 R.P.M. respectively, and the power feeds 94, 84, and 75 revolutions per inch of feed. The object of having two spindles in this machine is to save time by roughing and finishing a job on the same table. One spindle is fitted with a roughing cutter, and the other with a finishing cutter, *see* Fig. 157, Plate XII., which are used in succession.

Progression. — *See* **Arithmetical Progression**, and **Geometrical Progression**.

Projectile.—Omitting notice of the small bullets and cartridges, the manufacture of ammunition in the shape of explosive shells is a large section of the work of the founder and machinist, and numbers of machines are employed in this work.

All projectiles now are pointed, or ogival in shape, the old spherical shells having gone out with the smooth-bore guns. The elongated cylindrical form, with the rifling ensures that the point shall strike first, with resulting explosion. The diameter is less than the bore or calibre of the gun by from two to four hundredths of an inch. A band of soft copper is fitted into a groove near the base, having a diameter slightly larger than the bore. When the projectile is forced into the bore, the soft metal fills the bore, and the rifled grooves closely, and prevents gas from escaping past it. Projectiles are either *canister*, or *shrapnel*. The first contains a number of balls of lead or iron, with a charge of powder. The shock of firing bursts the shell, and distributes its contents from the muzzle. The shrapnel is made with a case strong enough to resist the shock of firing. It contains a large number of balls of lead or iron, and a small charge of gunpowder. The bulk of the charge is usually towards the rear of the shell, and is in communication with a fuse. Projectiles of this kind are of two types, common shell, not used against armour, and armour-piercing shell with caps. To the first-named belong the time fuses, which are adjusted to explode the charge short of the objects they are designed to destroy, as bodies of men, or forts. Percussion fuses must strike an object before they will explode. The time fuse is ignited by the shock of the actual discharge.

The armour-piercing shell is made strong enough to go through the armour, and explode only after it has gone through. This has altered the old design of thin shell, with a large bursting charge. Strength is ensured by the use of cast and forged steel, but some sacrifice of bursting charge has to be made to ensure strength. The fuse is not placed in the point, as in the common shell, but in the rear, where the fuse explodes a percussion cap, and ignites the charge.

The increase in the hard resisting qualities of armour plate has given birth to the shell of chrome steel, tempered. Still this shell became broken on impact until the soft-nosed projectile was devised. That is, the hardened nose of the shell is fitted with a cap of soft metal which protects the hardened nose from too sudden shock, and permits of penetration being effected.

The manufacture of projectiles is somewhat different according to the particular type. The following is generally applicable. Ingots are cast, and then worked by forging, followed by turning, and rounding the nose to the correct curve with a broad forming tool. A groove is turned for the copper band. The cavity for the charge is bored, and the hardening done. The base is threaded to receive the plug of steel which closes the cavity. The band is next put on in an hydraulic or power press. *See* **Banding Press**. Afterwards the band is turned. The soft steel cap is fitted and forced on by hydraulic pressure into a narrow groove. The mechanism for the various fuses, the nose type, the base fuse, and the time fuse are made on automatic machines and turret lathes.

Projection.—*See* **Orthographic Projection**, and **Perspective**.

Pronged Chuck.—*See* **Forked Chuck.**

Prony Brake. — A form of absorption dynamometer used to ascertain Brake Horse Power. It encircles a revolving flywheel, or a

pulley with which it makes frictional contact by means of two wood blocks screwed up and adjusted for tightness, until a lever arm connected thereto remains in a horizontal position. At the larger end of the lever a Salter's balance is attached at one end to the lever, and anchored at the other to any rigid object. The weight of the lever itself is counterbalanced by a small weight hung on the short arm. The number of revolutions per minute is read by a speed indicator, and the pull by the spring balance. Then $HP. = \frac{2\pi r n P}{33,000}$, where r = horizontal distance from the centre of balance to centre of pulley shaft, n = number of revolutions per minute, P = reading by Salter's balance.

Proof Bars.—The test bars used to note the progress of **Cementation.**

Proof Load, Proof Strain.—A proof load is one which is put upon a bar, chain, or structure in excess of the actual working load by a predetermined amount. It must not be so much in excess as to strain the material beyond the elastic limit, but must be sufficient to more than cover all legitimate working loads. The term *proof strain* is often used as the equivalent of proof load, though strictly it signifies the deformation produced by the loading.

Proportion.—The ratio of one quantity to another is the number of times the first quantity contains the second. The ratio of 12 to 3 is 4, because $\frac{12}{3} = 4$. Similarly the ratio of 36 to 9 is 4. When four quantities are concerned, and the ratio of the first to the second equals the ratio of the third to the fourth, the four quantities are said to be in proportion. The example above would then be set down, 12 : 3 :: 36 : 9, and read "12 is to 3 as 36 is to 9." The first and last quantities are the extremes, and the second and third, the means. In any proportion the product of the extremes equals the product of the means, as will be seen in the above example. Therefore if three terms are given the fourth may be found. *See* **Rule of Three,** and **Unitary Method.**

Proportional Compasses.—A form of dividers used for the purpose of enlarging and reducing dimensions, avoiding that stepping out which is necessary with ordinary compasses. The instrument comprises two flat slotted pieces formed into points at each end, and connected together by slides fitting in dove-tailed grooves in each piece. A central pin unites the slides, and constitutes the axis on which the slides pivot. Graduations on the faces enable one side to be set in a definite relation to the other, so that when the slides are clamped together by a nut on the pivot, and the points are spread apart, the distances of the latter correspond in a definite relation to each other, such as twice, or three times. A scale of circles is divided down one side, by means of which a circle can be divided around its circumference into any number of equal parts. Scales of plans, and scales of slides are also frequently added, the use in the first case being to reduce or enlarge the area of a plan in a certain proportion, and in the second to enlarge or reduce the contents of a solid proportionately. *Wholes and halves*, or bisecting compasses serve only for division into half, or enlargement to twice a length. The two legs are pivoted upon each other by a fixed joint.

Protective Coatings.—Numerous are the coatings which are applied to articles in iron and steel to protect them from the oxidising influence of the atmosphere, and from other chemical actions. Paints are by far the most commonly used (*see* **Paints**). But there is a large field for which these are unsuitable. A brief survey of the principal methods in use may be given. The method of coating of small articles with a layer of magnetic oxide, Fe_3O_4, is treated under **Barffing.** Its applications are very limited.

The *Gesner* process resembles the Barff in the fact that the metal is made to protect itself by its own oxidation, but instead of the formation of magnetic oxide the Gesner produces a compound of hydrogen, iron, and carbon, which does not scale off, and which does not increase the size of the articles materially. The colour is a deep blue-black. The articles are heated in clay retorts to a temperature of from 1,000° to 1,200° Fahr. for about twenty minutes, when steam is admitted through a pipe, becoming decomposed. Afterwards naphtha is injected for several minutes, followed by a further supply of steam. The whole period of treatment lasts about an hour and twenty minutes. The

articles remain in the muffle until the temperature has fallen sufficiently to permit of their removal without scaling.

The processes of *bronzing* and colouring iron and steel are very numerous, and large numbers of recipes might be given from various sources did space permit. The different colours and tints which are obtainable are taken full advantage of in fine art work, and in small pieces of mechanism which it is desirable to protect from corrosion. Very often colouring is combined with processes of hardening or tempering, sometimes colouring is done subsequently. Such colouring is mostly due to surface oxidation. In a large number of instances the process is one of electro-deposition. In all such processes the film formed is extremely thin, and is usually permanent, that is it will not crack or break away from the metal, but can only be worn off by friction.

Coal tar is a protective for rough surfaces, such as those of iron piles, and the interior of water pipes. An important feature is that the article to be coated should be of the same temperature as that of the tar, which is applied hot. The tar collected from the hydraulic mains of gas works is boiled in open kettles to concentrate it by the dissipation of the light oils, benzole, naphtha, and carbolic acid, the bulk being reduced by from 15 to 25 per cent.

Galvanising has an extensive use for some classes of work. But it is not suitable for work of very large dimensions, nor for work that is long exposed to corrosive influences. Acids attack it, and rust begins in any unprotected spots (*see* **Galvanised Sheets**).

Enamelling is not used much in engineers' work, and that principally for ornamental castings, and in the hardware trades. The enamels are thin coatings of glass of various colours, produced by the oxides of metals, ground, and mixed with a fluid, laid on as a paint, and fused in a muffle. A flux powder, the borosilicate of lead, is applied before the actual glaze powder.

Lacquering is a process applied less to engineers' work than in the hardware and metal trades. It belongs to the same division as the paints, as distinguished from the chemical processes, and is therefore liable to peel off (*see* **Lacquer**).

Tinning is a process which, though protective, is of a specific application to that of coating thin steel sheets with a fine film of tin, chiefly for domestic utensils. *See* **Tinned Sheets**. It is also adopted for the protection of copper culinary vessels.

Bright Machine Parts.—These can be protected and discoloration prevented by rubbing with a mixture of equal parts of lard, oil, and kerosene, or with vaseline. Or with one part of crystallised carbolic acid, mixed with twelve parts of sperm oil.

Protractor.—Is an instrument used for the laying down of angles. It is shaped as a circle, semicircle, quadrant, or merely a straight and broad scale. It is made of electrum, brass, steel, boxwood, vulcanite, celluloid, or horn. Its use is shown in Fig. 159. Suppose it be required to draw an angle of 30° at the centre of the line AB. The centre of the bottom edge is placed at this point, and a mark made at the figure 30 on the opposite edge. The protractor is then removed, and these points joined. The number of degrees in an angle may be measured in a similar way.

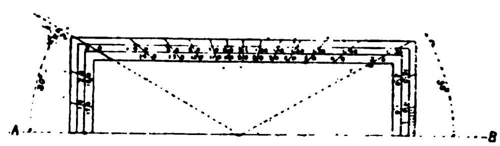


Fig. 159.—Protractor.

Proving Pump.—A pressure pump used in testing pipes.

Puddle.—A well-kneaded mixture of stiff clay which is used to render reservoirs watertight. Some clays are naturally impervious, but most have to be tempered. Almost any clays are suitable, but some are better than others. They should be quite opaque, and free from crystallisation and gritty matter, and should form a paste when mixed with water. Puddle must be tempered by breaking it up, cutting, cross-cutting, and grinding in a pug mill, or by exposing it to the atmosphere to be disintegrated by rain, frost, and changes of temperature.

A test of well-tempered puddle is to work it into a roll about $1\frac{1}{2}$ in. diameter, by from 10 in. to 12 in. long. If this will bear suspension

from one end while wet, without fracture it is sufficiently tempered. Or a mass may be formed with a hollow, into which several gallons of water will be poured, and left for twenty-four hours to test its impenetrability. Puddle is spread in layers not exceeding about 6 in. thick. Each layer is worked into the one beneath to ensure uniform consistency, and the absence of joints or hollows. If a layer has been exposed for a considerable time, it must be cleaned and watered before another layer is added.

Puddled Steel.—Steel prepared in the puddling furnace by the same methods as those used in puddling iron, only that the iron is subjected to a farther stage in decarbonisation. The only difference in the furnace is that the grate is smaller for steel, and the fire-bridge is rather higher, giving room for a greater depth of fuel, so that a high temperature may be secured. The pig is charged in quantities of about 4 cwt. at a time, and is rich in carbon and manganese. The method is hardly employed now, though at one time it was practised on the Continent for the manufacture of bars, to be subsequently remelted for the production of crucible steel.

Puddlers' Candles.—The flames of carbon monoxide, which arise from the surface of the charge in a puddling furnace during the boiling stage.

Puddlers' Mine.—A soft variety of red hæmatite, used for the bottoms of puddling furnaces.

Puddling.—The production of malleable iron in a reverberatory furnace by contact with oxidising or fettling materials. Practically all puddling is done by *pig boiling*, as distinguished from the original *dry puddling*, invented by Cort, in which the air was the oxidising agent.

Dry Puddling.—In this, the bottom of the furnace was lined with sand, and afterwards with iron bottoms, and white or refined iron only could be used. In later furnaces a layer of oxide of iron was spread over the sand bottom. The charge, when at the pasty condition, was rabbled or drawn about from the sides to the centre of the furnace, to mix the metal with the oxide of iron produced by the oxidation of the iron when in the pasty condition, and with that produced by hammer scale, added. A vigorous reaction takes place when the latter is introduced, the carbon being oxidised, and the carbonic oxide escapes. At the same time the other elements present are more or less oxidised, passing into the tap cinder. As little slag was formed, the term dry puddling was applied to this, when the pig boiling process came to supplant it.

Pig Boiling.—This is more economical than dry puddling. Grey and inferior ores can be used without producing inferior iron, as would be the case if inferior iron were employed in dry puddling. The refining for white iron is therefore dispensed with. Grey iron containing its carbon in the graphitic form, the charge becomes more liquid than in dry puddling. In pig boiling the furnace is lined with a layer of tap cinder, broken slag, hammer scale, and old broken hearths, which are all rich in oxides of iron. These materials are first fused and spread over the bottom to a depth of about 3 in., and then covered with a fettling of puddlers' mine —a red hæmatite. The side plates are fettled with bull dog, or roasted tap cinder, followed by puddlers' mine. The process of wet puddling may be divided into four stages. Temperature and working differ in some respects with the class of iron used, whether grey, white, or a mixture of both. In the first stage, the melting down takes place, during which part of the silicon is removed, and grey iron converted into white. The conversion of graphite to combined carbon is essential, because the latter only is sensibly affected by the oxides in the fettling, and the oxygen in the air. This stage lasts about half an hour. In the second stage, the temperature is lowered, and the charge is mixed with the fluxes and cinders by rabbling the metal from the sides to the more fluid central areas. This lasts about six minutes. In the third stage, occupying about twenty minutes, the heat is increased, and the characteristic boiling takes places, due to the escape of carbonic oxide. The manganese, sulphur, and phosphorus are mostly eliminated during this stage. Rabbling is done during this period to promote the oxidation by the air, and by the slag and cinders. At the close, the charge

drops and becomes pasty. This is followed by the *balling* stage, in which the metal is broken up and rolled towards the fire-bridge for a welding heat, before being withdrawn for treatment in the hammer, or squeezer, and thence to the puddle rolls for the production of No. 1 iron preparatory to piling.

The loss of metal in puddling is rather heavy, but it varies much with the ores used, and the degree of care taken. It varies from as low as 5 per cent. to 18 per cent. of loss between the weight of pig iron charged, and puddled ball yielded. About a ton of coal is used for a ton of bars produced. A charge consists of about 4 cwt., and a puddler with his mate can work off from five to seven heats during a shift of twelve hours.

Puddling Forge.—*See* **Puddling Mill.**

Puddling Furnace.—A reverberatory furnace of special construction for puddling iron. The roof slopes downwards from over the fire-grate to the end where the stack is situated. A fire-bridge separates the hearth from the fire-grate. It is of cast iron, water-cooled, and protected with fire-brick. The flue-bridge is at the opposite end next the stack, and between them lies the hearth; about 6 ft. in length, and from 3 ft. 9 in. wide next the fire-bridge to 2 ft. 9 in. at the flue-bridge. The furnace bottom and sides are of cast-iron plates, enclosing the fettling. The fire-grate is large, its area being about one-third that of the furnace bed. The *firing hole* is to one side over the grate, and about 10 in. above it. The *working door* is at the same height above the bed of the furnace, being a sliding door, counterbalanced, and opened and closed by a lever and chain. This is used for the introduction of the charges, and removal of the puddled balls. The rabbling is effected through a small opening—the *stopper hole.* The slag is drawn through a *tap hole* below the working door. Double puddling furnaces have two working doors on opposite sides of the furnace, and two sets of men: 12 cwt. of pig can be charged in these, with economy in fuel and fettling.

Numbers of furnaces are now fired with gaseous fuel on the regenerative principle. They much resemble open-hearth steel furnaces, using gas producers and regenerators. The linings are different. Types are, the Siemens, the Price, and the Ponsard, the latter having a rotating hearth. There are also mechanical puddling furnaces, rotary and otherwise, among which are the Clough, and the Danks. *See* **Rotary Furnaces.**

Puddling Mill.—Comprises the reheating furnaces, and the rolls in which finished iron is produced. The puddling forge contains the puddling or iron-making furnaces, and the hammers, squeezers, and forge rolls for producing the puddle bars. The reheating furnaces are larger than the puddling furnaces. The mill rolls, like the forge rolls, comprise two sets, the roughing, and the finishing rolls.

Puddling Rolls, or Forge Train.—The rolls which produce No. 1 bar iron from the ball or bloom of the puddling furnaces, after it has passed under the hammer, or squeezers, and so been shingled. They comprise roughing, and finishing rolls in one train. The first named are grooved in oval, gothic, or diamond shapes, and roughened with chiselled cuts. The second have flat grooves, which impart the bar sections. The bars produced range from 3 in. to 7 in. in width, by from $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. in thickness. The puddled bars are cut up, and piled for reheating, and re-rolling for merchant bars.

Pug Mill.—A rotating mill for pugging clay, that is, kneading and mincing it to a homogeneous state of consistency. Knives are arranged inside the cylinder to cut the clay, and turn it over so that a thorough amalgamation takes place. Pugging mills are driven by horse gear, or through belt pulleys and gearing. The clay is delivered through an outlet at the bottom, and forced into the moulds for bricks or other products.

Pulley.—A pulley is a grooved wheel turning about its axis. A pulley block contains a series of pulleys enclosed between side cheeks. The pulley is a widely used, and valuable device for changing the direction of motion, or transmitting power. It is included among the mechanical powers. As with the others the mechanical advantage is represented by the ratio $\frac{W}{P}$, W representing the weight or resistance, and P the power or force to overcome it. If W is less than P, that is, if the fraction is

less than unity, the pulley works at a mechanical disadvantage. Theoretically the cord is perfectly flexible and friction is absent, two conditions which are far from being non-existent in practice.

In the fixed pulley, Fig. 160, A, there is no mechanical advantage, the weight and the power balancing each other. A weight of 1 lb. requires a power of 1 lb. to balance it, or more than 1 lb. to move it. A fixed pulley is useful in changing a pushing into a pulling (downward or horizontal) force, and for changing the direction of motion generally. The presence of friction, however, renders it possible for equilibrium to exist when W and P are unequal.

A single movable pulley is shown at B. This type is used on cranes. One cord (or chain) is attached to a beam (or jib head) at a, and the other passes over a fixed pulley. If the cords are parallel each assists equally in supporting the weight W, and therefore the stress in each is $\frac{1}{2}$W. Thus $P = \frac{W}{2}$, the power is only half the weight, or the weight is twice the power. The mechanical advantage of the single movable pulley is thus equal to 2. As the cords depart from the parallel position the mechanical advantage decreases, so that when the angle made by the two supporting cords reaches 120°, P must equal W, and the advantage of the movable pulley is lost. As the angle increases beyond this, work is done at a disadvantage.

By combining a number of pulleys, it is obvious from what has just been said that a combination of many pulleys will give a still greater mechanical advantage. That is so theoretically, but in practice, the friction of an increased number of strings sets a limit to the number of pulleys it is possible to combine. These combinations are usually alluded to as the first (separate string), second (single string), and third systems of pulleys.

The arrangement in the first system is shown in the diagram at C. Remembering that the tension is the same in every part of the cord, the tension in the cord marked 1 is P. At the pulley block a, P supports a weight equal to 2P. The tension then on both parts of the second cord supporting the block b is 2P, and the weight

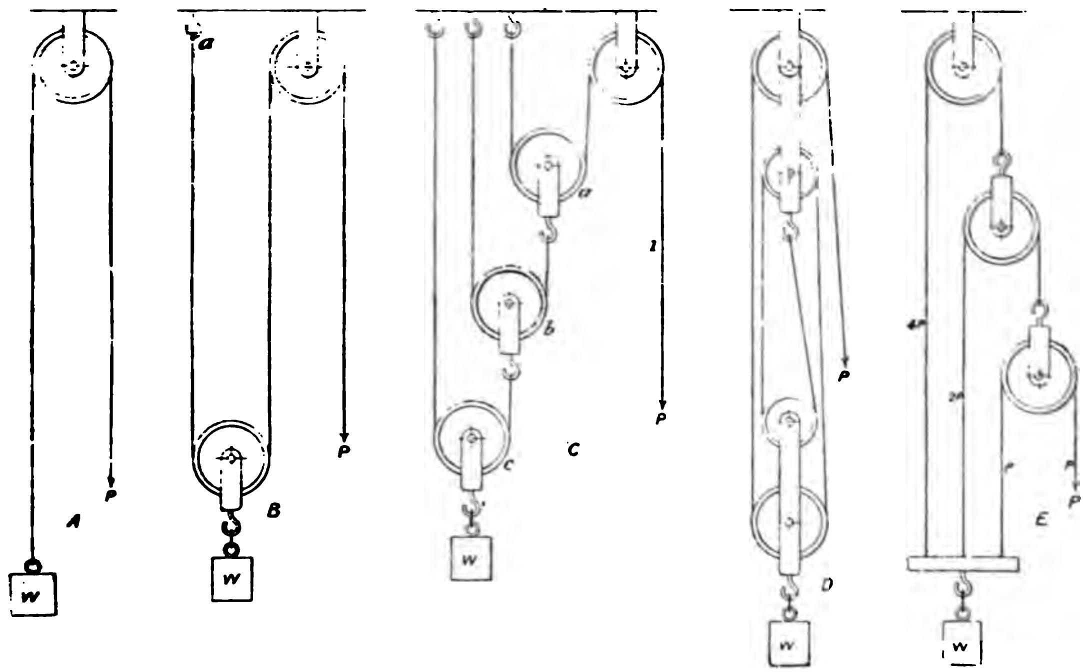
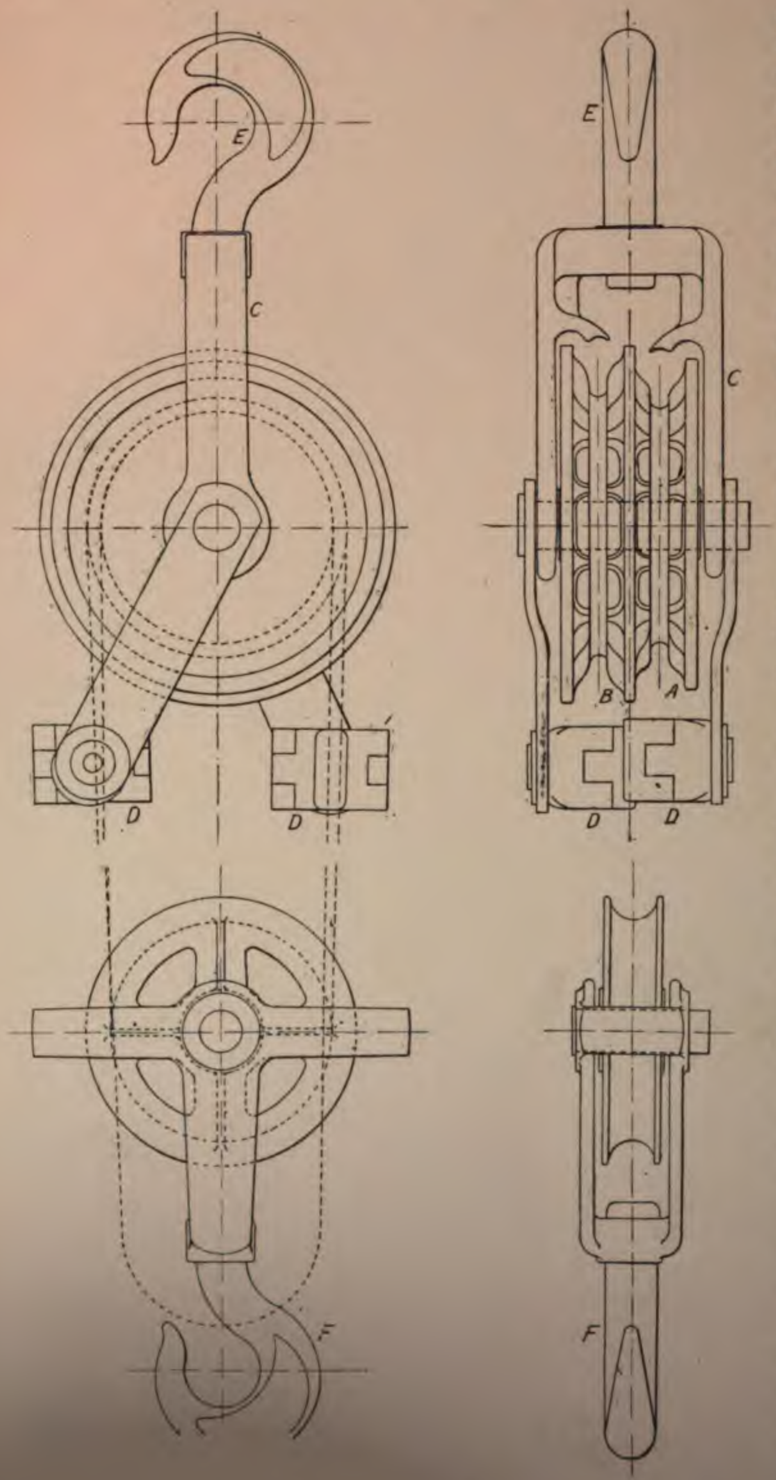


Fig. 160.—Pulleys.



supported equals 4P. 4P is the tension on the third cord supporting the block C, and the weight W, supported, equals 8P. Each additional pulley doubles the mechanical advantage, an obvious inference from the investigation of the single movable pulley. The mechanical advantage of any number of pulleys in this system is found from the formula $\frac{W}{P} = 2^n$, where n is the number of pulleys used. With one pulley $\frac{W}{P} = 2^1$ or 2; with two pulleys, 2^2 or 4; with three pulleys, 2^3 or 8, and so on. This system is not of much practical use.

In the second or single string system, the same cord passes round all the pulleys as shown in the demonstration diagram at D. In practice the pulleys are enclosed in two blocks, the upper one fixed and the lower one movable, and this system is very generally used. The tension throughout the whole cord is again P, and W is supported by four cords; therefore $W = 4P$. With any number of pulleys in the *lower* block, $W = 2nP$, n representing that number of pulleys. Mechanical advantage thus $= n$.

The third system is illustrated at E, each string being attached to the weight. It is really an inverted separate string system. In practice it

proves to be next to useless. As shown in the diagram,

The tension in the first string = P.
„ „ second „ = 2P.
„ „ third „ = 4P.

Pulley Blocks.—*The Weston Block.*—In a sense this has been the parent of all modern pulley blocks, because it was the first made which was able to sustain its load. It embodies the principle of the Chinese windlass, but two

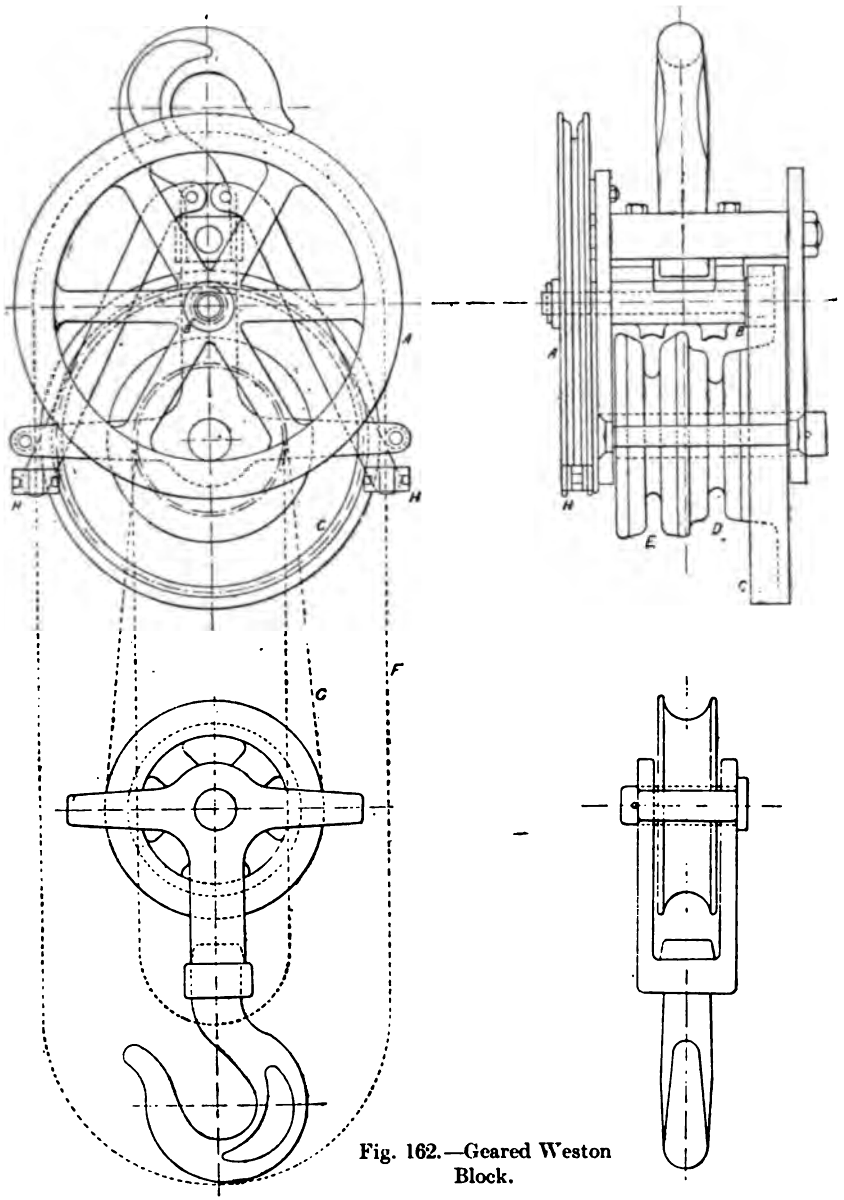


Fig. 162.—Geared Weston Block.

The sum of these tensions = 7P, or $(2^3 - 1)P$, the index 3 being the number of pulleys. For any number of pulleys, therefore, $W = (2^n - 1)P$, and mechanical advantage $= 2^n - 1$.

iron sheave pulleys, recessed for chain, take the place of the original drum, and the chain is substituted for the rope. The same endless chain is used for hauling by the hands, and for lifting.

The excessive friction of the Weston block, which is equal to more than half the work put into it, is at once its valuable feature, and its drawback. This explains the reason of the numerous designs which have been made to reduce the friction without sacrificing the advantage. But in all such cases a brake of some kind must be employed to sustain the load, either in the form of a worm gear, or of frictional faces.

The original Weston blocks are used as much as ever for ordinary service in shops and out of doors. They have no complicated or delicate mechanism which might become damaged by fair usage, or by weather. But their efficiency is only about 30 or 40 per cent., while that of other blocks ranges from 60 to 75 per cent.

Fig. 161 illustrates a 10 cwt. Weston block as made by Tangyes, Ltd. The pulleys A, B are cast together, and their pin has its bearings in the strap C, which has projections coming over the chains to prevent them from jumping out of their grooves. D, D are the chain guides pivoted around the pulley pin, which prevent the locking of the chains, and permit the loose loop to be pulled at a very considerable angle with the loop that lifts the load. E is the hook by which the tackle is suspended, and F the hook to which the load is attached.

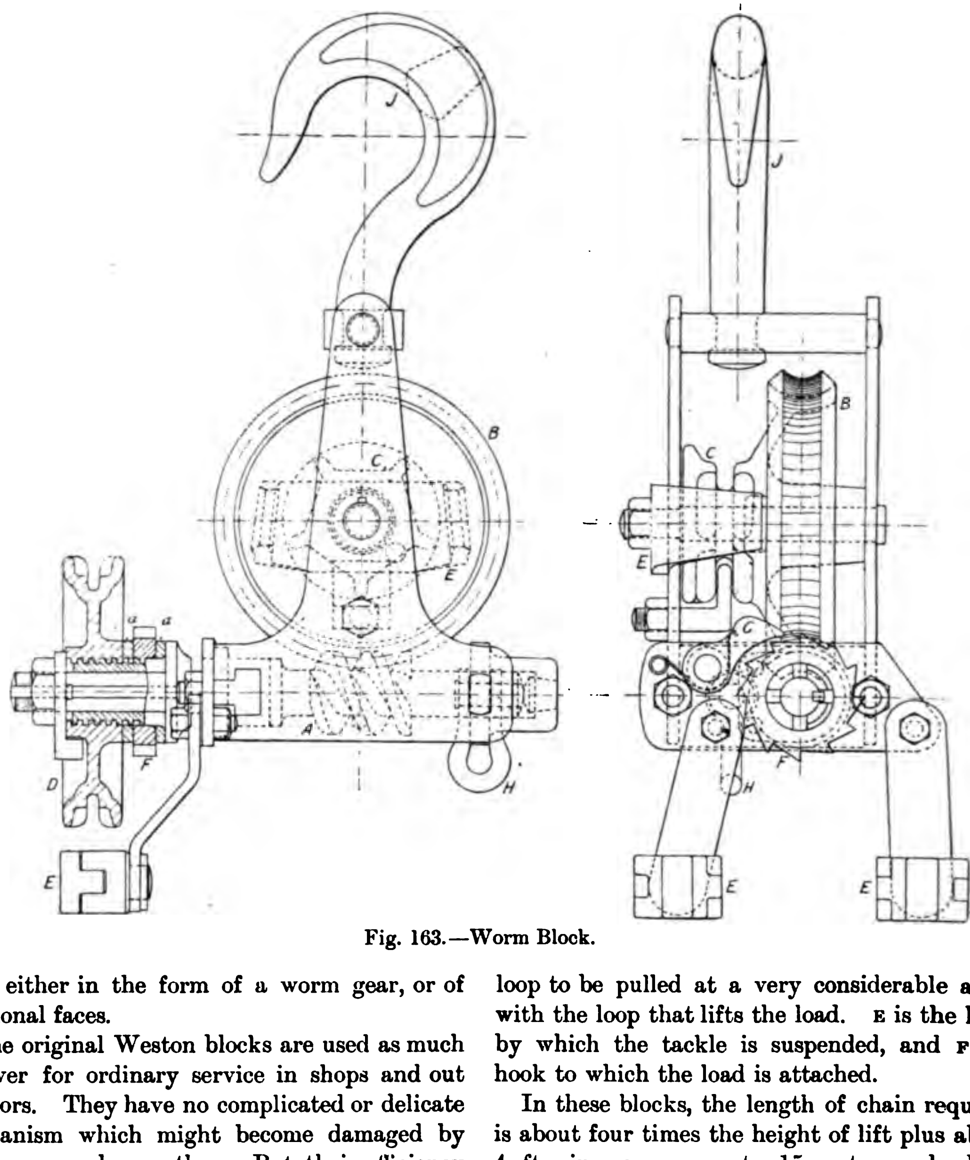
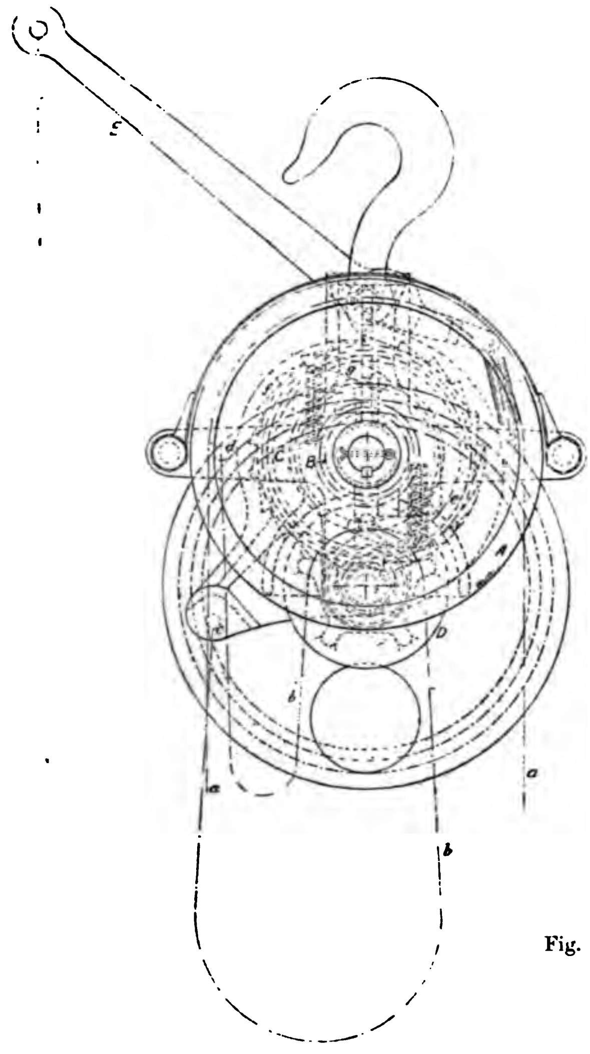


Fig. 163.—Worm Block.

In these blocks, the length of chain required is about four times the height of lift plus about 4 ft., in powers up to 15 cwt.; and about 6 ft. in the 1 ton and $1\frac{1}{2}$ ton sizes; and 8 ft. up to 4 tons.

Geared Weston Block.—Fig. 162 illustrates the Tangye block of this type, which embodies the Weston design, with the addition of the gain of extra power through a small and large gear wheel. A is the hand chain wheel which actuates a pinion B, engaging with the internal gear C, on the axis of which the sheave pulleys D and the double-threaded worm, B its worm wheel, the bearings of both being carried in the framing of the block. C is the hoisting chain sheave, cast with the worm wheel. D is the hand chain sheave which actuates the worm. E, E are the guides which prevent the chain from jumping out of the recesses in the sheaves,



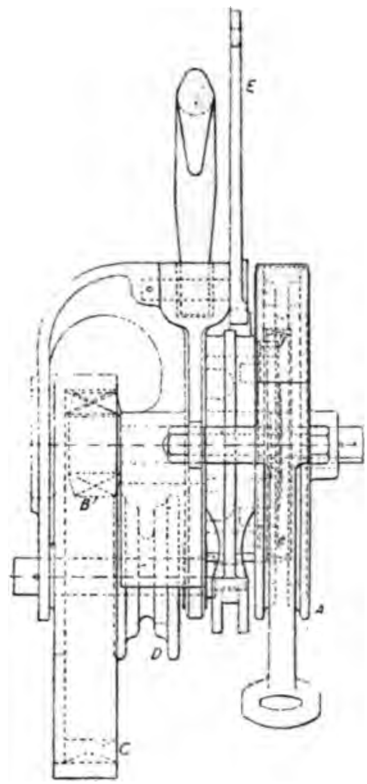


Fig. 164.—Cherry Block.

E are secured. F is the hand chain, G the hoisting chain, H, H are the guides for the hand chain.

Tangye's Worm Block.—This is a block of high efficiency, due chiefly to the fact that the worm is double threaded. The hand, and hoisting chains are distinct. In Fig. 163, A is F is the ratchet, G its pawl, having a leaf spring; H is the anchor for the fall of the hoisting chain, J the suspending hook. The pulley D is fitted to its sleeve with a screw, and movement in one direction or the other, by pulling on one or the other side of the hand chain, makes or breaks contact with the ratchet

F, through the leather washers a, a interposed between the faces. The frictional contact set up, and the engagement of the pawl with the ratchet, makes the blocks self-sustaining. The make and break are effected instantly, and the load is lowered instantly by the steep pitch of the double-threaded worm.

Cherry Block.—The original Cherry block was made with differential bevel wheels, one of which had a difference of one tooth, or more, less than the other. The hand chain wheel was attached to the first bevel, the lifting chain wheel to the other, so that the latter received a slow and powerful motion from the former. The bevel wheels worked face to face, and the teeth were engaged successively by an eccentric pin boss, giving a kind of swash plate motion to the first bevel. The Cherry block as now made by Messrs Tangyes, Ltd., is shown by Fig. 164. A is the wheel for the hand chain a, on the shaft of which wheel is the pinion B, engaging with an internal ring of teeth C, the latter driving the wheel D for the lifting chain b. The latter is anchored at c and d. As long as lifting goes on by the hand chains, the brake drum e within the hand chain wheel is rotated by means of a ratchet f, and two spring pawls g, g. But if lowering is to be done by the brake, the lever E is pulled by its cord, and the brake strap is released from the drum.

The Yale & Towne Triplex Chain Block.—This is a powerfully geared block, and one in which the hand chain and the chain for lifting the loads are distinct. Also the functions of lifting and lowering are separated, the latter being effected by an automatic friction brake mechanism. The block is shown in Fig. 165. A is the endless hand chain, and B its sheave pulley. C is the lifting chain, and D its pulley. E is the ratchet wheel running with B. When lifting is being done it turns in the direction of the arrow. F is its pawl, kept in contact with the teeth by a spring. The ratchet E tur freely on the hub G, keyed to H, but the shea B is caused to make and break frictional conta

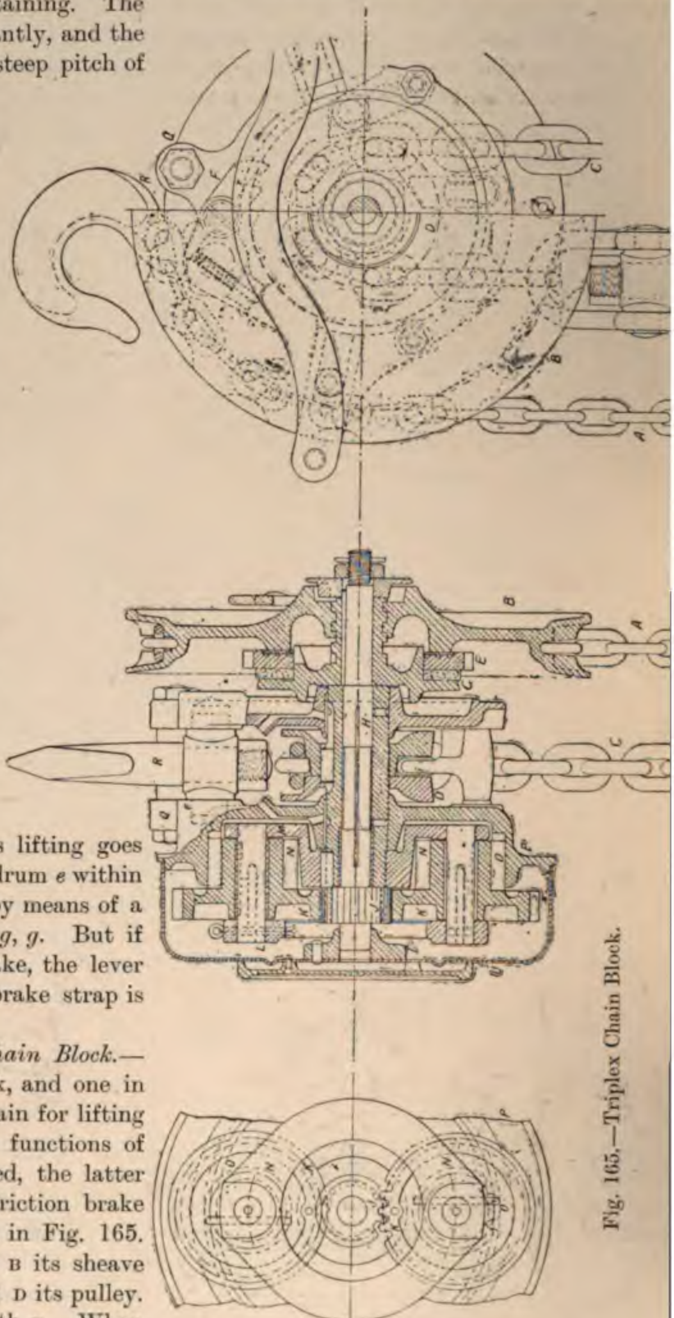


Fig. 165.—Triplex Chain Block.

with the ratchet E by a quick pitch, coars threaded screw, by means of which it is carri

Fig. 156.—Profile Milling with Form Cutter.
(Alfred Herbert, Ltd.)

Fig. 157.—Table and Outfit for Profile Milling.
(H. W. Ward & Co.)

Fig. 166.—Pulley-Turning Lathe.
(The Niles-Bement-Pond Co.)

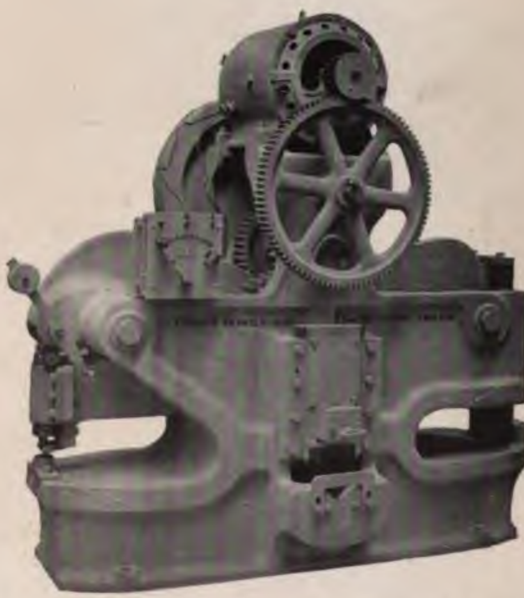


Fig. 174.—Lever Punching and Shearing Machine.
(Francis Berry & Sons.)

To face page 152.

on the hub of G, and is tightened or released against the leather between G and E by pulling at opposite ends of the chain A. The friction discs are released by reversing the hand chain, when the load descends smoothly by the slipping of the discs on each other, on spinning the chain A. The spindle H carries the pinion J which drives wheels K and K in perfect balance, the pins being carried in rotating bearing plates L and M. Solid with K, K are the pinions N, N, and these engage with teeth O on the plate P, which is a portion of the main framing of the block. Lugs Q on this framing receive the pin of the hook R, by which the block is suspended.

The gain in power in these blocks is that first between pinion J and the wheels K, K, and then from K, K to the pinions N, N and ring of teeth O. K and N are bushed to run on their pins. The plate M is keyed to the revolving sleeve S, to which the lifting sheave wheel D is screwed in two sections. The spindle H has a bearing at the end opposite to the hand chain sheave in the boss E attached to the plate U, which encloses and protects the gears.

Pulley Lathe.—A special type of lathe employed solely for turning pulleys after they have been bored; they are put on a mandrel and driven between centres, by an equalising driver, while slide rests at front and back carry cutting tools to operate on the rim and edges. Fig. 166, Plate XII., illustrates a good type of machine, for 50-in. pulleys; it will be noted that the lathe outline is considerably modified. The headstock carries a spindle and face plate driven by worm gearing from a six-step cone, for 4-in. belt; the shaft of this cone runs at a much higher speed than the mandrel, and advantage is taken of the fact to fit suitable mandrels into it, for carrying pulleys which have to be polished, the attendant doing this operation while the turning is proceeding. The two slide rests are supported on saddles that can be moved in or out to suit the diameter of pulley, and they may be set at an angle, to impart the crowning which is substituted for a curve in so many cases in present practice. A self-acting feed is given to each rest.

Pulley Moulding Machines. — The moulding of belt pulleys from complete patterns made in wood is rarely done, the patterns being too expensive in the first place, and too flimsy in the second. Standard pulleys regularly turned out, are moulded from iron patterns, jointed and dowelled through the middle plane of the arms. But this does not meet the requirements of jobbing work, nor of all standard work, in which differences are made in width, and in mass, or straight across, or with different amounts of crowning. In shops where pulley moulding is done by hand, the custom is to have two sets of iron rims, one light, the other heavy, and two sets of loose arms, light, and heavy. The rims are all of one width, 12 in., or 15 in. or 16 in. Narrow pulleys are moulded by stopping off the depth, very deep ones by drawing the rings in the mould. The arms are centred by a gauge. Special boxes are made, circular, or hexagonal, to hold the minimum of sand. The rims are turned inside and out, and the arms got up neatly. Excellent moulds are made in this way. But the moulding machines do the same for pulleys as for other work,—they ensure an accurate, vertical, and steady lift, without rapping, and distortion. There are several designs, some simple, others elaborate.

The elements of a pulley moulding machine are: a stand supporting an outside stripping plate, and carrying an internal sliding arrangement by which the pattern rim is drawn down through the mould and between the external, and an inside stripping plate, after ramming. The arms are carried on the inner stripping plate. The moulding boxes are fitted by pins to the machine, the same pins by which each part box is registered to its fellow, each box part taking half the pulley depth. In some cases hydraulic pressure is employed for the withdrawal of the pattern, in others a hand-wheel and screw.

Pull-Over Mill.—Denotes a rolling mill which is non-reversible, and in which, therefore, the plate or bar has to be lifted over or pulled over the top roll in order to be passed through the same rolls again.

Pulsometer Pump.—A pump, Fig. 167, the motive power of which is provided by the alternate condensation and pressure of steam acting on the water or other liquid being pumped. The pump body is a single casting, formed chiefly of two separate pear-shaped chambers, with provision for inlet and discharge, and suitable

valves, which are either of the grid, or other type, depending on the particular duty required. At the top of the casing where the two chambers meet, there is a ball-valve with just enough of lateral play to permit it to close

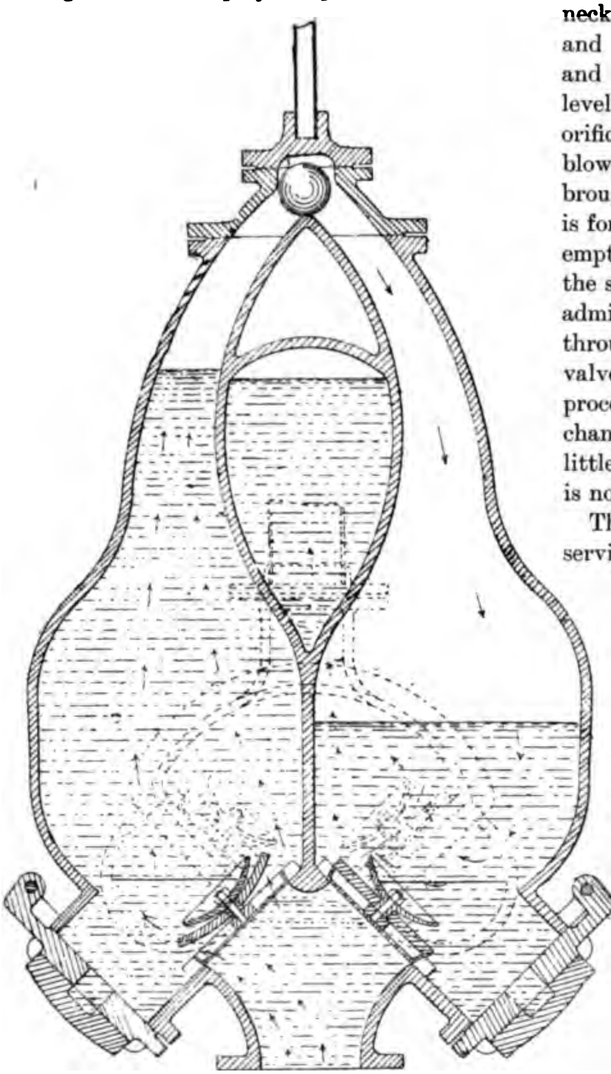


Fig. 167.—Pulsometer Pump. (The Pulsometer Engineering Co., Ltd.)

either one of the two steam inlet openings leading into the chambers. At the bottom of the chambers there is a suction passage from which the liquid has access to both chambers through valves. A discharge common to both chambers receives the liquid through other valves. The action is as follows:—

When the pump is to be set to work, the chambers are filled with water, and steam is admitted through a pipe and makes its way into one chamber,—whichever one happens to be left open by the position of the ball in the neck. It presses on the water in the chamber, and drives it through the discharge opening and valve into the rising main. When the level of the water is as low as the horizontal orifice that leads to the discharge, the steam blows through. But being at the same time brought into contact with the water, a vacuum is formed almost instantly in the chamber just emptied, and the ball-valve is pulled over on the seat of that chamber, preventing the further admission of steam. Water then rushes in through the suction pipe, lifting the inlet valve, and filling the chamber. The same process now goes on in the other chamber. The changes are so rapid that without an air vessel little interruption in the continuity of the flow is noticeable.

The Pulsometer is suitable for a wide range of service, including the raising of sewage, sludge, mud, sand, &c. It will raise from 15 to 50 per cent. of foreign matter in combination with water. These pumps are made in sizes to throw from 1,000 to 150,000 gallons per hour.

Pumping.—*See* **Feeding.**

Pumping Engines.—The term was formerly understood to denote Cornish engines, but it now includes rotating types. Pumping engines are used for drawing the water from mines, and in waterworks service, in condensing plants, on land and on board ship, in each of which a broad and definite type has been evolved.

Mine Engines.—The Cornish engine, though much out of date now, did its work excellently and economically. Its non-rotative character was one of its chief recommendations, for the pause at the end of the stroke conduced to the regular action of the pump valves. The pause permits the valves to fall on their seats by their own weight, with less wear and tear than when they are closed forcibly, and the cost of repairs and renewals is lessened. The expansive working of the steam under almost ideal conditions,

ribed under **Cornish Engine**, gave a
gh duty. The momentum of the descent
pump rod was an essential feature in the
g of the Cornish engine, in the absence
wheel. The rotative beam engine has
sed largely for mine pumping. But it
e useful pause at the end of the stroke,
speed is not sufficiently slow.
st any horizontal or vertical engine may
for mine pumps; simple, or compound,
r tandem, generally condensing, with
, or Corliss valves, and of all dimensions.
connections of the engine to the pump
e of special design; gearing down is
l. A pinion on the flywheel shaft
a large wheel, with a reduction of 1 to
. The latter drives the pump spear rod
a bell crank lever, or *bob* lever, so con-
the rotary motion at the flywheel to a
reciprocating motion at the spear rod
ves.

erworks' Pumping Engines.—Beam
both simple and compound, have been
used for this class of service, but they
lom made now, having been superseded
er types, some rotative, and either verti-
horizontal, others direct-acting. Of the
he Worthington has been one of the
ccessful. The independent steam feed
lesigned in 1841, was the first in which
n and pump piston were attached to
ends of a piston rod. In 1854 the
terworks engine of this type was built,
1863 the first duplex engine. *See*
ington Pumping Engine.

ps for Ships and Docks.—The best for
urposes are those of centrifugal type.
e variously fitted, being belt driven, or
coupled to an engine mounted on the
se plate, or two may be driven from a
ngine. The work of erection is nearly
le. They require no air vessel, are not
amaged by sand and grit, will pump hot
and give a high efficiency. *See* **Centri-
Pump**.

ps.—Machines for raising fluids. The
l kinds are treated under their suitable
See **Air Pump**, **Centrifugal Pump**,
Pump, **Force Pump**, **Hydraulic**
ing Engines, **Lift Pump**, &c.

Pump Spear.—The rod which operates deep well pumps. It is made of wood, as being less liable to vibration than metal. Georgia pine is a suitable wood, balks or planks being fished together. The weight of a pump spear is often several tons in the case of very deep wells.

Punch, Punching.—Any tool which is used to stamp holes in material is a punch. Or a tool which marks shallow recesses, as a centre punch. Punched work includes that done in all metals and alloys, in leather, cloth, indiarubber, card. Punches may be of any cross section, many being used for stamping flat chain links, blanks for all kinds of press-work, &c. But the majority of engineers' punching deals with round holes in sheets and plates of very sensible thickness, in which certain precautions have to be observed that do not arise in very thin work.

Punching is a detrusive action; that is, it is produced by the exercise of strong pressure, as distinguished from that which is percussive, or hammer like. The stress is very severe during a brief period, but as soon as the metal is severed, which occurs almost immediately after contact of the punch with the plate, the pressure ceases. Even in the most powerful machines there is thus a distinct pause in the action at the instant of greatest stress, almost amounting to a momentary pull up. The resistance of a plate to punching is about equal to that to resist a tensile stress. The resistance equals the area of the hole, plus the thickness of the plate; thus, $d \times \pi \times t \times s$; where d = diameter of hole, t = thickness of plate, s = tensile strength of material. The resistance, therefore, increases directly as the diameter of hole, thickness of plate, and strength of material.

The strength of the punch determines the thickness of plate which can be punched. A hardened steel punch has a compressive strength of 100 tons per sq. in. If the compressive strength of the punch is over four times as great as that of the tensile strength of the plate, it will punch a hole having a diameter equal to the thickness. This sets a limit to thickness, and in practice no attempt is made to punch through so great a thickness, but thickness is always less than diameter.

A very important detail is the amount of clearance in the *die*, or *bolster*. So long as there is sufficient, the exact amount is immaterial. It varies from $\frac{1}{32}$ in. to $\frac{1}{8}$ in. in smaller and larger punches. To attempt to punch with a bolster of exactly the same diameter as the punch would stress the plate and the machine excessively. And the hole in the bolster must always taper downwards. This allows the punching, or *wad*, and the hole to assume the shapes which result in least stress; that is, a wad, and hole both larger in diameter at the lower end than at the top. The fact that the hole is tapered does not matter, the rivet fills it, but in the best work it is reamered parallel to remove the burr. M. Tresca showed that the action of punching is of a plastic character. Under the severe stress set up, the wad becomes compressed, without increase of density, and a large portion of the metal flows laterally into the plate.

The punch can hardly be classed as a cutting tool, though it is tapered back by a degree or two for clearance, and therefore has an angle just under 90°. The spiral punch is much better as a cutting instrument, and is used, but not nearly to the same extent as the older form. Punches and bolsters should never remain in use after the cutting edges have become dulled. They often are, but with increased stress thrown on them, and on the machine, and with injury to the plate.

Effects of Punching.—The differences in the weakening effects attributed to punching are rather remarkable. Thus, Mr Barnaby in 1875 described some experiments which showed that the tenacity of steel plates might be reduced from 31 or 32 tons per square inch to 14½ tons by punching. On the other hand, experiments by Mr Riley in 1876 showed no loss of strength in bars of Landore steel punched, and unannealed. In connection with a paper by Mr Boyd in 1878, describing experiments which showed that punching diminished the tenacity of steel plates, Dr Siemens instanced experiments on punched steel plates which showed an apparent increase of strength by punching, an experience confirmed also by Mr Tweddell. These, however, must be considered as exceptional instances, because an overwhelming mass of evidence is in existence to show that punching weakens the resisting power of both iron and steel plates. It is possible that the size of die block, or bolster used has had an influence in producing these apparently contradictory results. With a bolster having a hole of about the same size as the punch, the loss of strength is greatest, probably because the metal immediately around the punched hole is severely compressed, and therefore in a different condition of elasticity from that surrounding it. Experiments communicated by Mr Kirk in 1877 showed that the loss of strength was much less when the hole in the die block was larger than the punch, than when both were of the same size. Other experiments by Mr Parker and Mr John in 1878 showed that with steel plates of from 0·675 in. to 0·712 in. in thickness, the effect of increasing the size of the hole in the die block was:—

Total taper of hole in plate.	Loss of tenacity due to punching.
$\frac{1}{16}$ in.	17·8 per cent.
$\frac{1}{4}$ in.	12·3 „
$\frac{1}{8}$ in.	24·5 „

With a large hole in the bolster, the evil is of another kind, but equally great as with too small a hole. The punched hole becomes ragged and torn, besides much tapered, and the metal consequently very much weakened. Other experiments have proved that the loss of strength due to punching depends partly upon the thickness of the plate. Without going into specific results, it has been proved that thin plates suffer much less than thick ones from punching. Plates punched with a helical or spiral punch were proved by Mr Martell to be 2½ tons per square inch stronger than those pierced with an ordinary punch.

In reference to the reason of the weakening due to punching, M. Barba's experiments (1873) led to the inference that the weakening is not due to cracking, or to a reduction of tenacity in the neighbourhood of the holes, but to an alteration in the elasticity of the metal, reducing the power of elongation in the narrow annulus surrounding the hole. The action of the punch causes metal to flow laterally into the adjacent surrounding metal. Initial stresses

are set up in that annulus, and the power of elongation being diminished there it gets more than its due share of the load, resulting in incipient fracture in that locality.

A Memorandum issued by the Board of Trade in 1885, on mild steel, for the use of their surveyors, contains some valuable information on the effects of perforating steel plates. The plates experimented on were $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in. thick, and they were all perforated by drilling, by punching, by punching and subsequent annealing, and by punching and subsequent boring or reamering. The plates which were drilled sustained the greatest stresses, those which were punched the least. The plates which were punched and annealed, punched and bored, bore about equal stresses, but both were inferior to the drilled plates. The percentage values of the perforated plates as compared with solid plates are given in two ways; one with reference to the gross area of the plates, that is including the metal removed by the holes; and the other with reference to the net area only, that is of the metal left between the holes. The latter is the method which is usually adopted by engineers, because it enables them to so proportion riveted joints as to ensure about equal strength for the shearing of the rivets, and the tearing of the plates. The only value of the former method consists in the facility which it affords for a comparison of joints similarly proportioned in plates of similar thickness. The stresses per square inch of net section between holes are given in the following table:—

Mean Stress per Square Inch of Net Section between Holes of Perforated Plates (Lengthway).

	¼-in. Plates.	⅜-in. Plates	½-in. Plates.	¾-in. Plates.	1-in. Plates.
	Tons.	Tons.	Tons.	Tons.	Tons.
Drilled - - -	29·40	30·21	29·60	32·38	29·49
Punched - -	25·92	27·27	22·70	21·96	18·18
Punched and annealed - -	28·07	28·61	29·99	29·26	27·11
Punched and bored -	27·23	28·54	28·11	30·69	28·08
Unperforated plates	27·10	26·60	27·20	30·20	27·10

And percentage values for the different kinds of perforations are given in the table succeeding.

Ultimate Stress per Square Inch of Net Section of Perforated Plates Compared with Unperforated Plates (Lengthway).

Unperforated Plates = 100.

	¼-in. Plates.	⅜-in. Plates.	½-in. Plates.	¾-in. Plates.	1-in. Plates.
	p. cent.	p. cent.	p. cent.	p. cent.	p. cent.
Drilled - - -	108·4	113·5	108·8	107·2	108·8
Punched - - -	95·6	102·5	83·4	72·7	67·0
Punched and annealed - - -	103·5	107·5	110·2	96·8	100·0
Punched and bored -	100·4	107·2	103·3	101·6	103·6

These tables are very valuable as showing the desirability of abandoning punching in favour of one of the other methods of perforation. And a plate not only suffers in ultimate strength by punching, but also in ductility, as the following table shows:—

Elongation of Holes in Perforated Plates at Ultimate Stress (Lengthway).

	¼-in. Plates.	⅜-in. Plates.	½-in. Plates.	¾-in. Plates.	1-in. Plates.	Mean.
	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
Drilled - - -	25·0	30·8	30·8	33·9	34·8	31·0
Punched - - -	10·4	11·6	6·1	3·1	1·9	6·6
Punched and annealed - - -	25·6	24·4	30·4	28·7	25·4	26·9
Punched and bored -	19·2	19·2	22·4	24·2	15·6	20·1

Another point is, that speaking generally, the perforations which coincide with high tensile strength and ductility also show silky fracture, while the others are either partly silky and partly granular, or wholly granular.

Punching Bear.—A portable machine for punching holes in plated work, and in repair work which cannot be reached by fixed machines. They include screw, duplex lever, and hydraulic types, illustrated in the figures, by Tangyes, Ltd.

The screw type is shown in Fig. 168. The body and screw are of wrought iron. These are made in four sizes, to punch holes of $\frac{1}{2}$ in., $\frac{3}{4}$ in., $\frac{13}{16}$ in., and $\frac{7}{8}$ in., given as through *iron* plates. Smaller punches and dies can be inserted in any machine than that for which they are designed, but not larger ones. The duplex

bears, Fig. 169, are made in similar sizes, but are of both open and close mouth designs. They are also made with a shoe to fix to a bench.

Hydraulic Punching Bear.—One of these, by Tangyes, Ltd., is shown in Fig. 170. It is of the open mouth type. The body A is of wrought iron. B is the water tank, with a wrought-iron bottom, screwed into the tank and the body. D is the pump, of gun-metal; E the plunger of wrought iron, actuated by the lever F, and handle slipped over the squared end G of the spindle. H is the ram, J the punch, and K its bolster. L is the stop-valve, M the cam by which the ram H is lifted by a handle (not shown) similar to that used for G; *a* is the ram leather. It will be seen that the design of the bear is essentially that of the **Jack** (*see* Vol. VI., page 27, Fig. 19). But in that figure the suction valve is in the pump body, while in this it is in the pump plunger, at *c*, and the delivery valve is below; *b* is the gauze for the suction inlet.

The bear is operated thus: the lid N is unscrewed from the cistern B, the punch is lifted as high as possible, and the cistern is nearly filled with a mixture of one part of glycerine to three parts of water. The stop-valve L is screwed up, and the lever on G is worked till the punch is through. The stop-valve is then unscrewed, and the punch lifted by the cam M to draw out the punch from its hole ready for another setting.

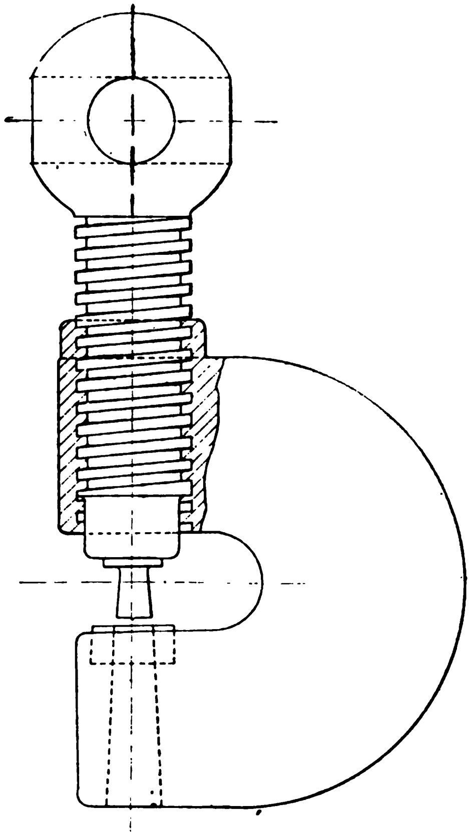


Fig. 168.—Punching Bear.

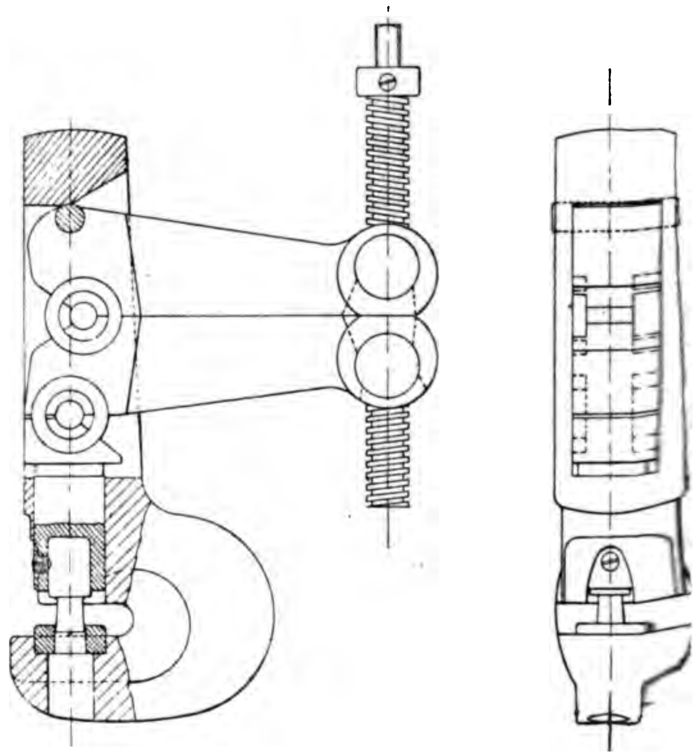


Fig. 169.—Duplex Punching Bear.

Punching Machines.—These are either fixed or portable. For the latter, *see* **Punching Bear**. The method of operation of the fixed machines is either by cam, or lever, or by direct hydraulic pressure. Very often the operations of punching and shearing are embodied in one machine. There is advantage and disadvantage in the combination, which must be taken account of by individual firms when making selection.

nching machines are driven by belt pulleys pur gear. A flywheel or a pair of wheels ted to equalise the turning moments. large machines are of independent type, is, driven with an engine bolted to the ing. Of late years motor driving is being ted.

rer Machines.—In these, one end of a is raised by a cam on the main driving , pushing the other end, which contains unch slide, downwards to its work. It is

A combined machine by Messrs Davis & Primrose, having lever motion, is illustrated in Figs. 171 and 172, the first giving the general arrangement of the frame and driving gears, the second details of the lever movements. In Fig. 171 the fast and loose pulleys A drive the top shaft fitted with two flywheels; and double gears, B, C, D, and E, drive on to the cam shaft F. In Fig. 172 two cams, *a*, *b*, also seen in Fig. 171, press upon hardened steel strips let into the undersides of the long levers G and H,

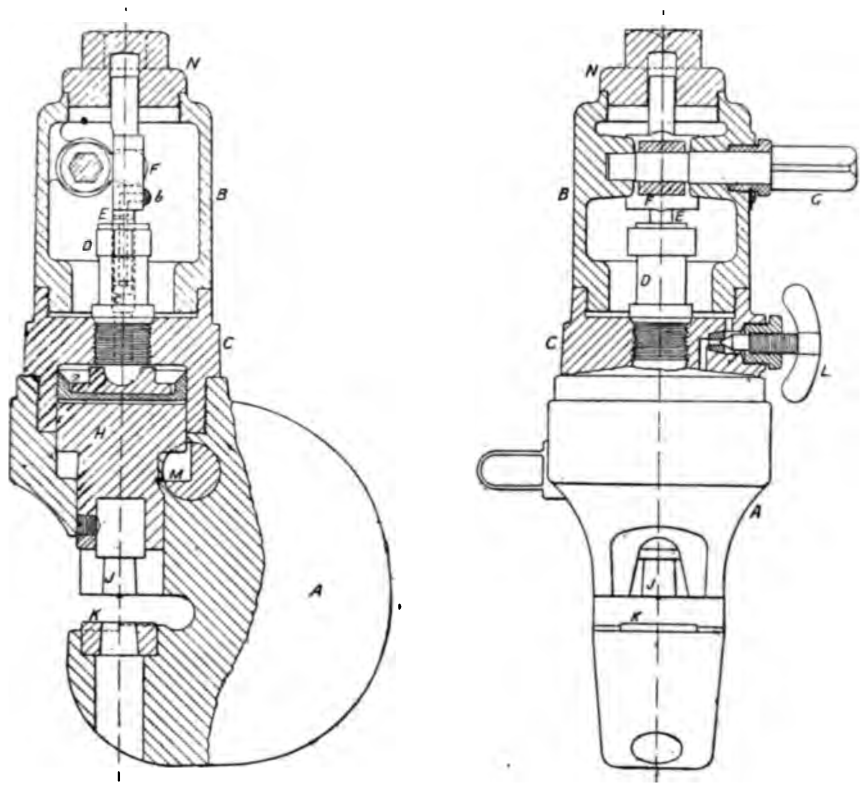


Fig. 170.—Hydraulic Punching Bear.

ed down by another cam to draw the h out of its hole. An advantage of the machine is that the speed of punching lifting can be varied by the shape given e cam, to provide a quick return. It is consonant with the operation of punching; in its descent, giving a *pause*, while the dant has time to adjust the plate or bar, to coincide with the severe stress of punch- and a rapid ascent, with economy of time.

and force them upwards, so that they pivot around the pins at *c* and *d*; they are pulled downwards by straps J and K acted on by other cams on the shaft. The shear blade slide at L encloses the end of the lever H by a slot, while the punch slide is moved by a short block that is thrown into and out of action by the lever M to work the slide N.

A complete drawing of a lever machine by Messrs Francis Berry & Sons is given in Fig.

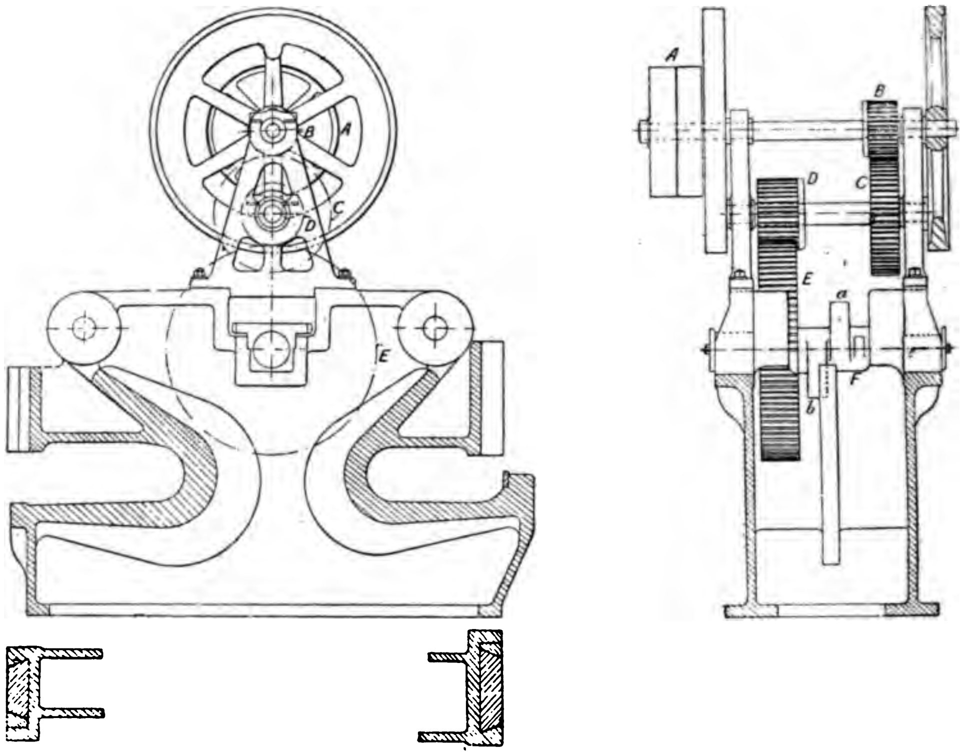


Fig. 171.—Lever Punching and Shearing Machine.

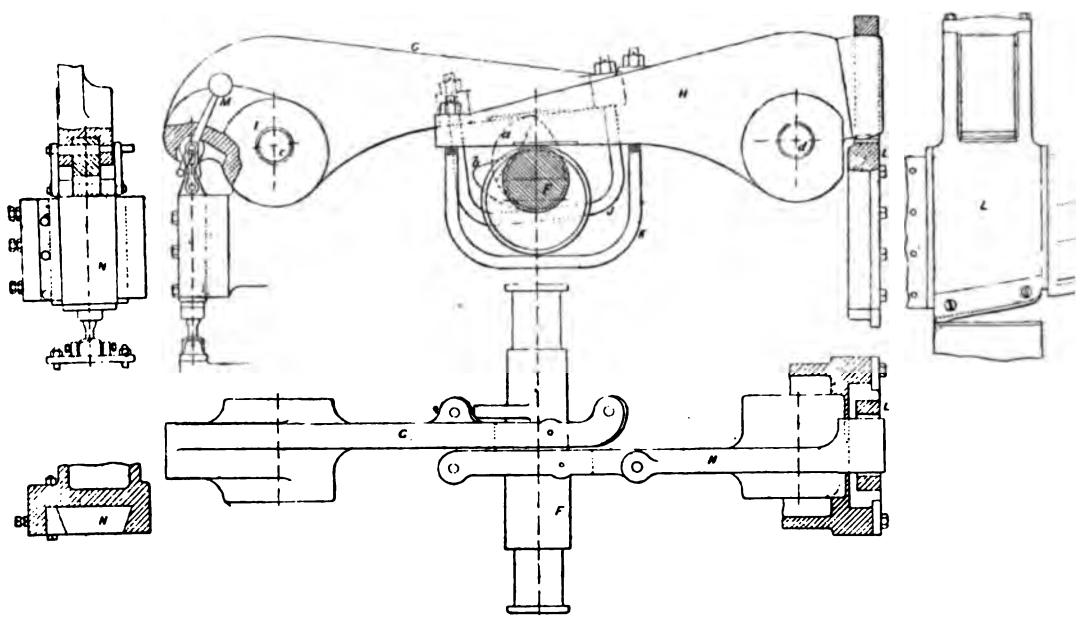


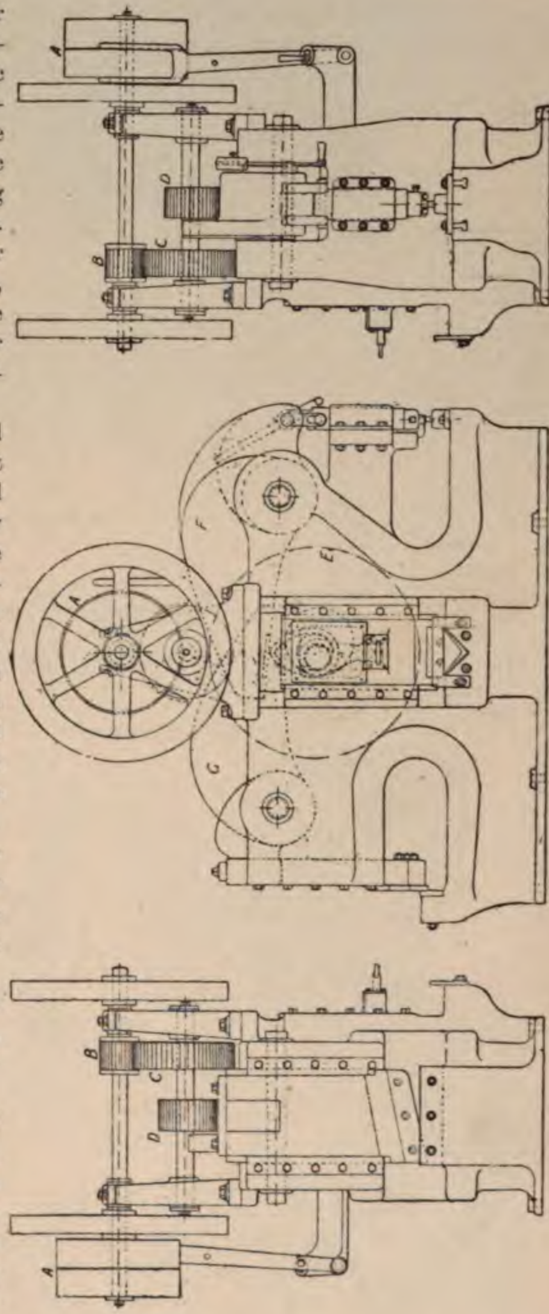
Fig. 172.—Lever Punching and Shearing Machine.

173. It includes an angle-iron shear at one side. The drive takes place through pulleys A, and spur gears B, C, D, E, the last being on the central shaft. A cam works the lever F for punching, and an eccentric the lever G for shearing, it having been found that the eccentric gives gradual movement better suited for shearing than that imparted by a cam. The angle shear blade slide is reciprocated by an eccentric on the end of the shaft, and a disengaging motion is fitted to this, and the punch slide also. The photo, Fig. 174, Plate XII., shows a similar class of machine arranged for electric driving, the motor being placed on the top of the frame and geared by a raw-hide pinion to a spur wheel which actuates the train of gears, operating in a similar manner to those in Fig. 173.

Eccentric Machines.—In these a pin is turned eccentrically on the end of the driving shaft (one at each end in combined punching and shearing machines). The amount of eccentricity is enough to impart the up and down stroke to the punch. The pin in its eccentric revolution moves in a slot hole in a rectangular block which has a horizontal movement in a recess in the punch slide, and so imparts the vertical movement to the latter. Or, in the Whitworth design, a triangular block receives the pin, and rocks in a triangular shaped recess with sufficient lateral clearance. In this design the up and down strokes are made in equal times. The only thing which can be done is to increase the lift of the slide, and run it at a higher speed. On the other hand, the thrust is more direct in an eccentric machine, and the framing is strained less.

A stop is inserted between the bottom edge of the sliding block and the recess in the slide, to be pulled out when an adjustment for punching is not completed.

Fig. 175 shows a combined punching and shearing machine by Messrs Davis & Primrose. It is of eccentric type, the shaft A running in bushes close to the ends, the eccentric pins project into square blocks (see the enlarged details B, C), which have a certain amount of side play in the punch and shear slides to permit of the eccentric movement. In the case of the punch slide there is a cam D thrown downwards by the handle to render the motion inoperative until the plate to be punched has been adjusted into position. The punch and bolster are shown



173.—Lever Punching and Shearing Machine.

in enlarged section at E. The eccentric shaft is driven from the top shaft by fast and loose

pulleys at F through pinion G, wheel H, pinion J, and wheel K; the slides reciprocate about eighteen times per minute. The stripper, which prevents the plate from rising with the punch on the upward stroke, is a screwed bar, with a turned-up foot, having a gap through which the punch passes. The strippers are seen in the machines when desirable, as shown in Fig. 177, Plate XIII., which represents a $1\frac{1}{8}$-in. machine; that is, one capable of punching $1\frac{1}{8}$-in. holes through plates $1\frac{1}{8}$ in. thick. Angle iron up to 5 in. by $\frac{5}{8}$ in. can be shorn by the blade situated near the centre. An electric motor drives the machine.

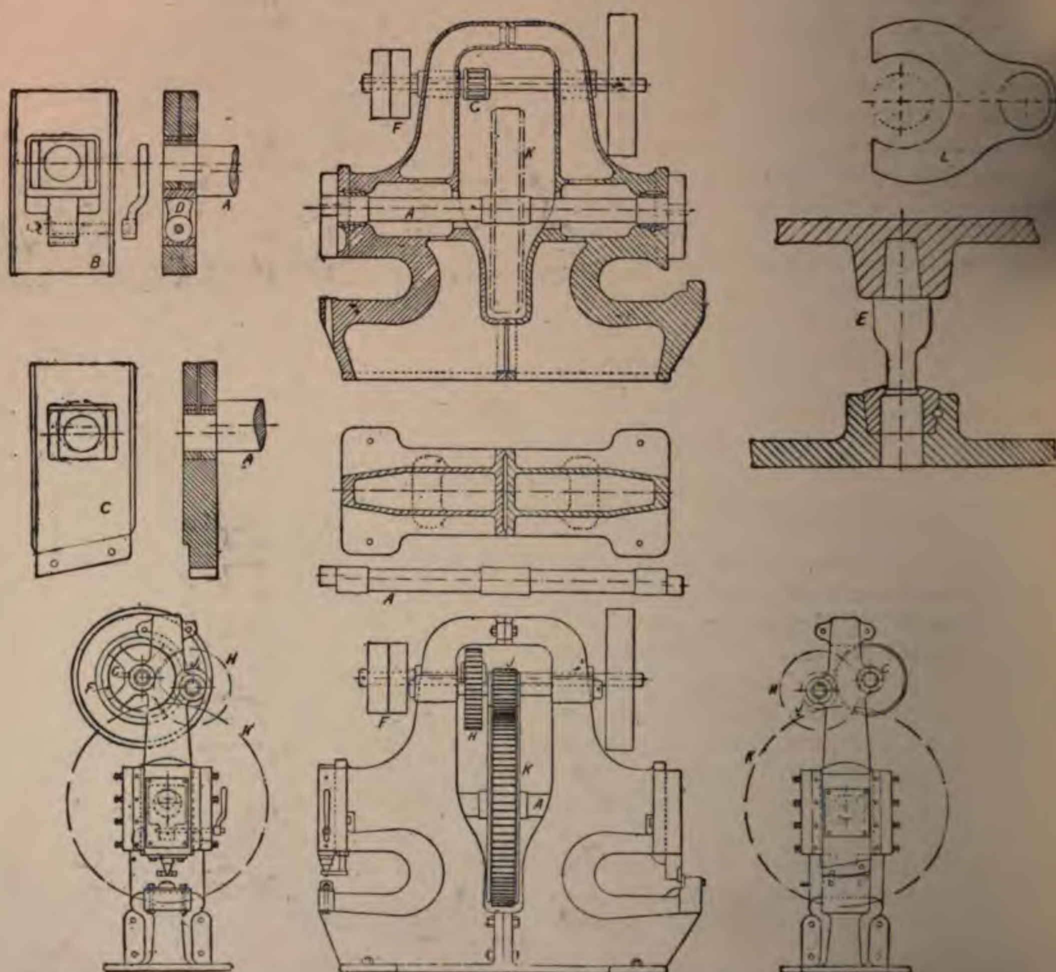


Fig. 175.—Eccentric Punching and Shearing Machine.

general views of the machines here shown, and an enlarged plan view is given at L, Fig. 175.

A motor-driven eccentric punching and shearing machine is shown in Fig. 176, Plate XIII., the motor, as in the case of Fig. 174, being coupled by a raw-hide pinion to the first wheel in the train. Cranes are fitted to the larger

Fig. 178 gives a side view of a combined punching and shearing machine by Musgrave Bros., operated hydraulically. There is a shear blade A set on the bevel, an angle shear B, and a punch C. Each of the slides is forced down by a ram in the cylinders D, D, D, and returned to normal position by a small return

176.—Eccentric Punching and Shearing Machine. (Francis Berry & Sons.)

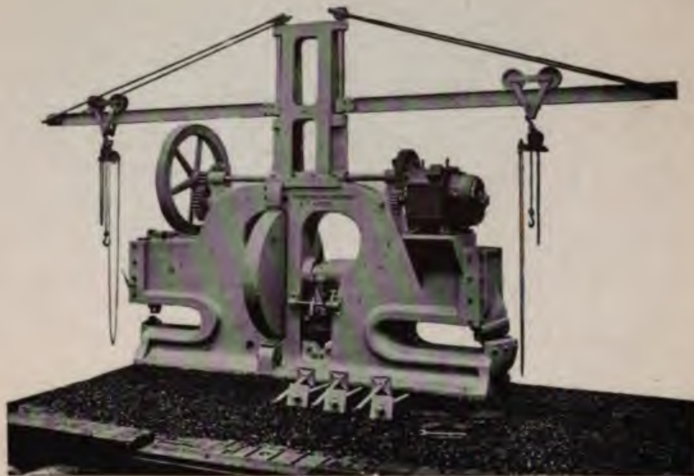


Fig. 177.—Eccentric Punching and Shearing Machine. (Fairbairn Macpherson.)

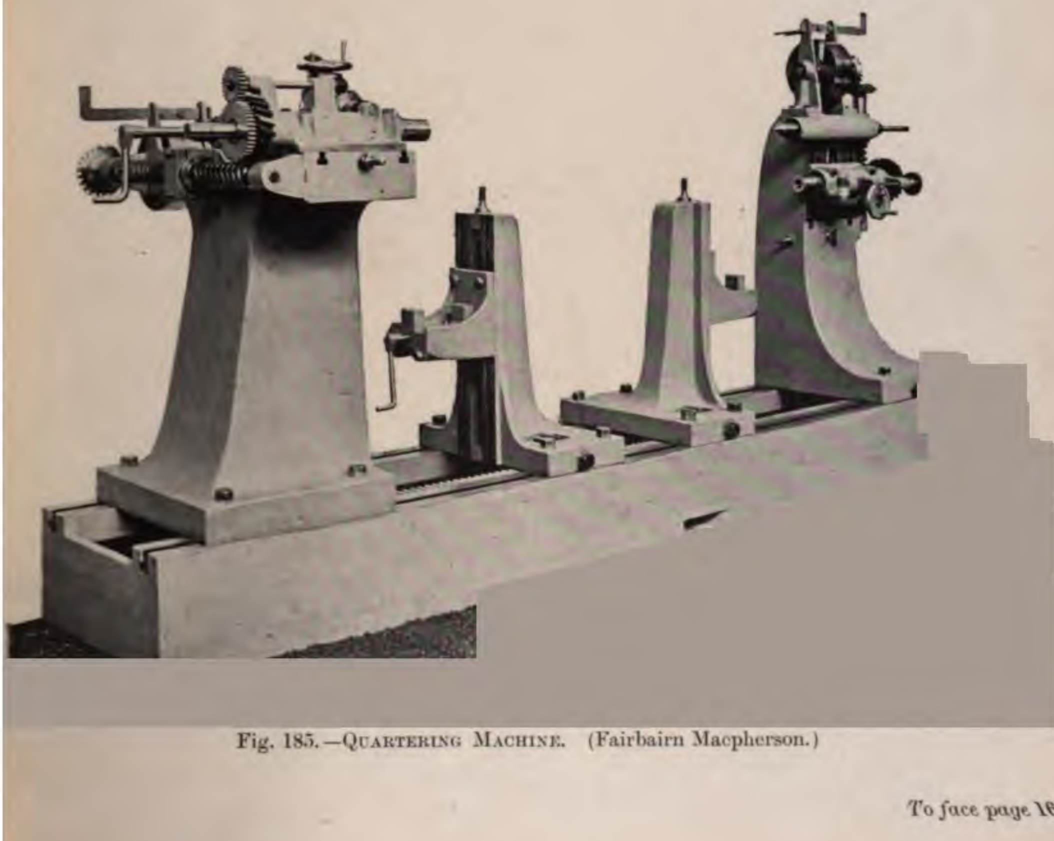


Fig. 185.—Quartering Machine. (Fairbairn Macpherson.)

To face page 162.

nder, E, E, E. The supply of water by the valve levers F, F, F. These made up to 36 in. in the gap, to shear plates up to 1 in. Many constructed without the shears, so ne is of bow form, with a gap more

section of a punching machine is und the *gullet*, or opening for the rs. It is strained by every detrusive ne metal becomes crystallised and Often these machines have fractured horizontal or diagonal direction. he metal here alone only aggravates setting up cooling strains. The be distri- reasonable d deep and d ribs cast. dii every- deeper the ore severe In com- chines the let should rower than unching, patterns the same

in which are built angle are ry Pels & Co., more especially for rolled sections. Most of these are e, avoiding the spring of the open es.

punching machines are used rking on bars which are slid along front of the punch.

unching machines are made for l, ship, and tank work, &c., a com- oles being pierced simultaneously. are carried at the bottom of a ciprocated up and down between ouple of eccentrics on a horizontal oupled by connecting rods to the ne cases a tapered strip backs up unches, so that they strike the cession, instead of all at once.

Some machines have the punch below, the shears uppermost, used chiefly for light duty.

Pyramid.—A pyramid is a solid having any plane figure for a base, and the sides are triangles whose vertices meet in a point at the top, called the apex or vertex of the pyramid. The pyramid is named from the shape of the base, as square, triangular, pentagonal, &c. The axis is the line drawn from the apex to the middle of the base, and when this line is perpendicular to the base, the cone is said to be a right one. The slant height of a pyramid is measured along the middle of one of the faces.

To find the volume of a pyramid:—Multiply

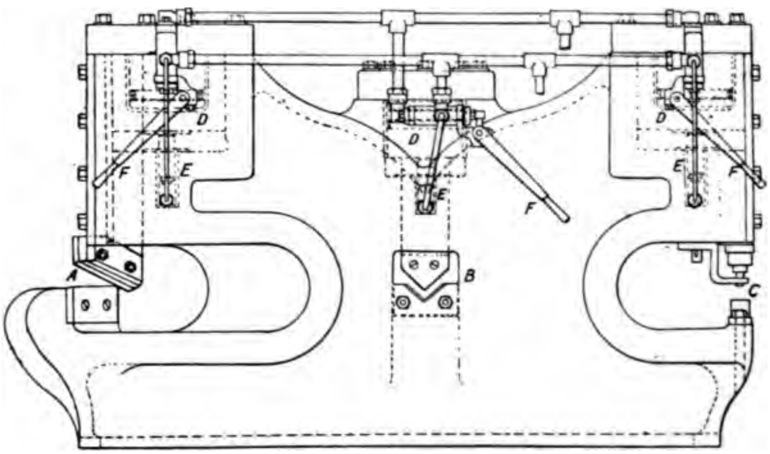


Fig. 178.—Hydraulic Punching and Shearing Machine.

the area of the base by the height, and take one-third of the product.

To find the volume of a frustum of a pyramid:—To the areas of the two ends of the frustum add the square root of their product; multiply the sum by the height of the frustum and one-third of the product is the volume.

Pyrometers.—Thermometers designed for measuring high temperatures, or literally, fire meters. They are often classed as thermometers, and some measure temperatures as low as the mercury and alcohol thermometers do. But it is convenient to make the distinction.

The utilities of the pyrometers have been vastly extended with the demands made for increased accuracy of temperature measurements, and with the lessening practice of rule

of thumb. Especially is this of interest to engineers, in the metallurgical industries, in melting and pouring metals and alloys, in hot-air blast main temperatures, in the heat treatment of steels, in hardening and tempering operations, in annealing, and in boiler engineering, where flue temperatures are important, and the temperatures of high-pressure steam in superheating. Outside of engineering proper there is a vast and growing field for pyrometry in brewers' mash tuns, in chemical works, explosives sheds,

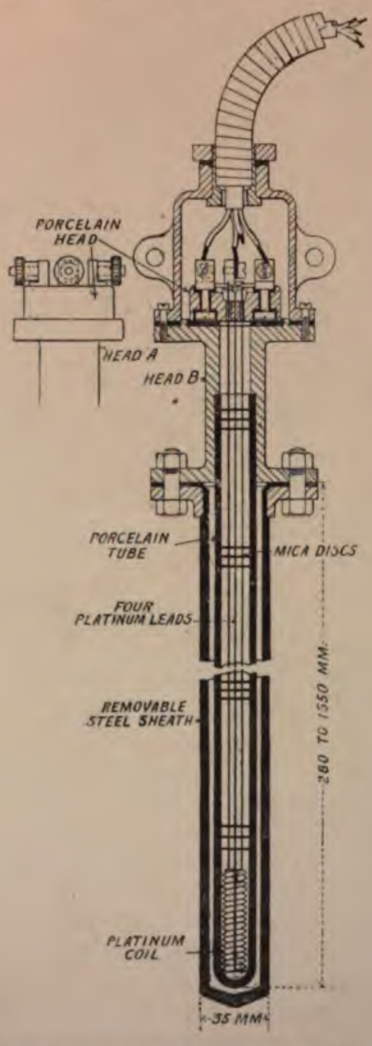


Fig. 179.—Resistance Thermometer for Annealing and Case-Hardening Furnaces, and Hardening Baths.

cold storage chambers, glass furnaces, brick kilns, jam boiling, &c. So varied, too, are the conditions, that different types of pyrometers have been designed to meet them. The types most generally used are the Resistance, depending on the variations in resistance of a platinum wire with temperature, the Thermo-electric, Radiation, and Absorption pyrometers. Approximately temperature measurements may be relied on as being accurate to within 1 per cent.

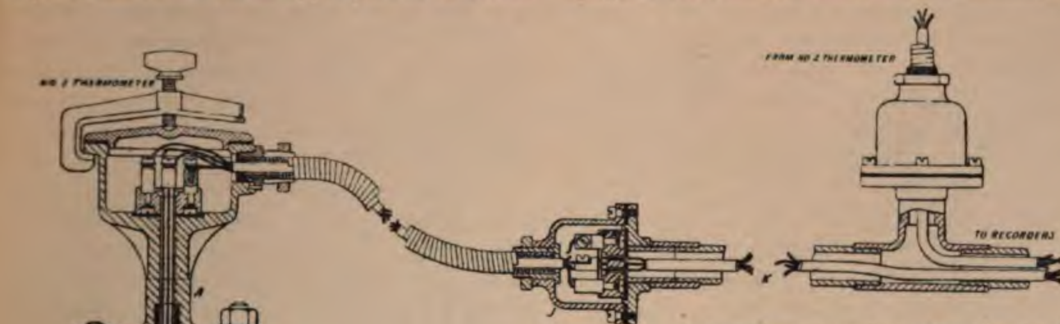
The value of the pyrometers lies to a large extent in the combination therewith of the automatic recorders. These generally register the fluctuations of temperature on a paper wound on a drum, and show in a graphic manner the variations which it is the duty of careful attendants to regulate and control. There is thus no longer any dependence on the trained eye judgment of colour tints, but an unskilled attendant can read, as also can his manager, the story of the fluctuations delineated on the paper wrapped round the recorder drum.

Resistance Pyrometers.—The essential element in these is a fine platinum wire of about half a millimetre in diameter which is wound on a mica frame, and which depends for its operation on the fact that resistance increases as temperature rises. In the pyrometers by the Cambridge Scientific Instrument Co., the resistance need not be known by the user, as the temperature is directly indicated by the instruments. It is usual to speak of the wire as the *bulb* of the instrument. It is contained in a tube of porcelain, and is connected by stouter wires to the recorder. For some purposes tubes of steel or brass are used instead of porcelain. There is no need to locate the recorder close to the pyrometer. In an installation at Woolwich the two are situated three-quarters of a mile apart. Compensating leads are so arranged that the temperature of the bulb gives the readings. The design of the pyrometers is varied to suit the numerous duties and industries in which they are employed. Generally for temperatures below 900° Cent. (1,650° Fahr.), the resistance pyrometers are suitable.

The Thermometer, Fig. 179, is suitable for taking temperatures of furnaces and flues, &c., up to 1,200° Cent., and is designed for use in annealing furnaces, hardening baths, galvanis-

ing baths, &c. It is provided with a cast-iron head with protecting flange, and with cover and union for holding connecting leads in flexible steel or copper tubing. It is also supplied without the protecting terminal cap, and with thumb terminals in place of the binding posts as shown in Head A.

Fig. 180 shows a thermometer designed for determining the temperature of hot-air mains; the instrument is shown inserted through the roof of the main. The pyrometer is enclosed in a porcelain tube with an upper part of cast iron.



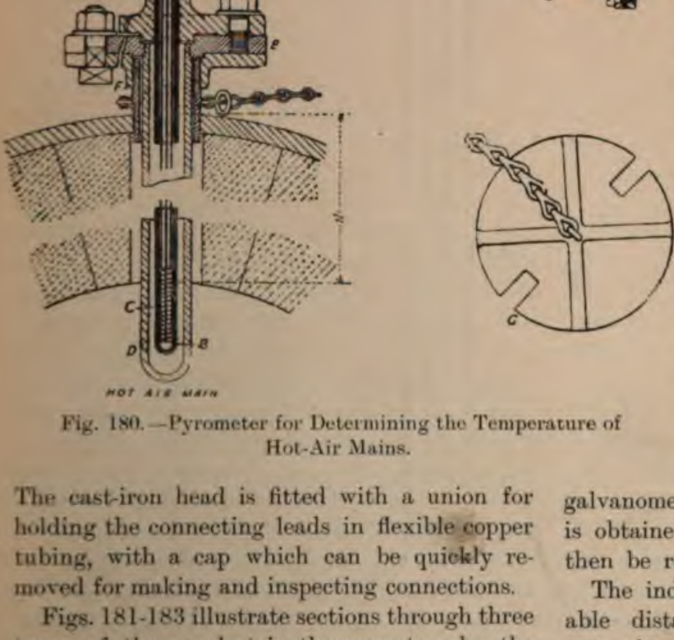


Fig. 180.—Pyrometer for Determining the Temperature of Hot-Air Mains.

The cast-iron head is fitted with a union for holding the connecting leads in flexible copper tubing, with a cap which can be quickly removed for making and inspecting connections.

Figs. 181-183 illustrate sections through three types of thermo-electric thermometers by the Cambridge Scientific Instrument Co., Ltd. Fig. 181 is employed for temperatures up to 1,400° Cent. (2,552° Fahr.) in high temperature furnaces, flues, &c. The tube is of porcelain throughout, the leads are of platinum, platinum-iridium, or platinum-rhodium; the heads are hard wood. Fig. 182 is also intended for similar temperatures to the above, in annealing furnaces, case-hardening furnaces, &c. There is a cast-iron head, with protecting flange, with a terminal cap and union for holding the leads in flexible steel or copper tubing. It will be seen that a steel tube or sheath surrounds the porcelain tube; this sheath is removed when temperatures above 700° Cent. are measured. Fig. 183 represents a very slender type of instrument, designed for research work, the determination of recalescent points, &c., where only a small amount of the substance to be tested is available. Temperatures up to 1,400° Cent. can be measured, but by removing the porcelain tube temperatures up to 1,600° Cent. are possible.

Indicators and Recorders. — Of these there are also several types. In the Whipple indicator the wires leading from the pyrometer are brought into a box containing a battery. By depressing a key, and turning a milled head, the resistance of the indicator is made equal to that of the thermometer, and a galvanometer needle stops when the balance is obtained. The temperature in degrees can then be read off on a scale.

The indicator may be placed at a considerable distance from the thermometer without the accuracy of the readings being affected. The instrument is so constructed that rapidly varying temperatures may be readily followed and measured. A series of thermometers distributed over a considerable area can be read from one central

station by means of an indicator and switchboard.

For recording, the Resistance pyrometer is connected to a Callender recorder, and a battery. The recorder automatically balances the resistance of the pyrometer by resistances in itself. When the temperature of the pyrometer varies, the balance of resistances being disturbed momentarily, the automatic restoration of the balance causes the pen to travel across the paper and register the temperature. When th balance is disturbed, a galvanometer tends t deflect to one side or the other and comple the circuit through one or the other of tw motor release magnets. A brake is th lifted and allows a motor clock to pull the p along until the balance is restored, thus givi a continuous record of temperature. Temper ture indicators or recorders can be connect to any one of a number of pyrometers by mea

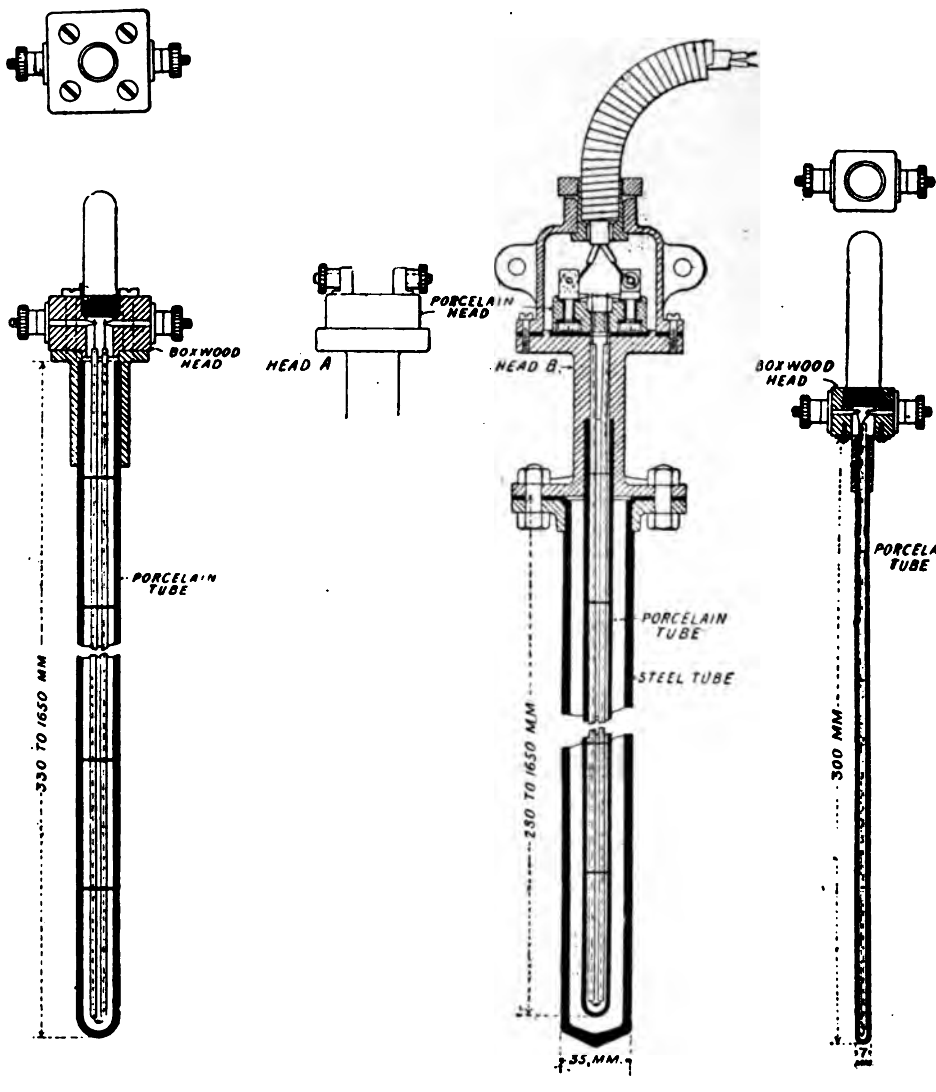


Fig. 181 Fig. 182. Fig. 183.

Thermo-Electric Pyrometers.

board and plug. A Callender re- be adjusted to suit a particular iperature. By means of zero coils s of temperature can be readily

ad Recorder. — This instrument, ;en recently designed and patented ıbridge Scientific Instrument Co., s essentially of a delicate recording r so arranged as to give a series of :he instantaneous deflections of a r boom. The method employed antage of producing continuously l whilst avoiding pen-friction. The r boom is suspended over a paper- m. Between the boom and the ked thread is stretched parallel to the drum, and at a short distance ırface. A presser-bar is situated alvanometer boom, the bar being d free of the boom by means of a gular intervals the cam makes a on, allowing the presser-bar to fall om, afterwards raising it again to eight. As the presser-bar falls it boom on to the drum, nipping the between the boom and the paper. nd has a knife edge on its under produces a dot upon the paper at intersection of the boom and the making a visible record of the in- deflection of the galvanometer. The r boom is hinged so that it can be thout bending the suspension. In between the production of the dots ıeter is, of course, free to take up its on without frictional errors. The e made to rotate once in two or hours, and the instrument can be make a dot every minute or every The instrument is designed for ıperature recorder in combination ry Radiation Pyrometer described an be used with thermo-electric The clockwork mechanism can lepress two or more galvanometer aneously, the various galvanometers ted to different thermometers. The ined are entirely independent of nd the thermometers may be work-ing over widely different ranges. If by any mishap one galvanometer or thermometer is damaged the others are unaffected. A scale for reading temperatures directly is fixed on the face of the presser-bar.

Thermo-electric Pyrometers.—These comprise essentially two fine wires of different metals or alloys which are fused together at one end. At the other end they are connected through a galvanometer. The fused end is placed in the source of heat. The difference in temperature of the two ends of the couple develops an electro-motive force which is roughly proportional to the difference in temperature. The couples used chiefly are of platinum and rhodium, or platinum and iridium. The most satisfactory couples have been shown to be:—

Platinum, platinum 10 per cent. rhodium for temperatures up to 1,600° Cent. (2,912° Fahr.).

Platinum, platinum-iridium for temperatures up to 1,400° Cent. (2,552° Fahr.), giving a more open scale than the former.

Copper-constantan for temperatures up to 500° Cent. (932° Fahr.), giving a very open scale. Iron-nickel couples are also employed, but are not greatly to be recommended owing to their want of durability. Electromotive force is usually measured directly on the galvanometer. For very accurate laboratory work a potentiometer is sometimes employed. The galvanometer used is one of high resist-ance. The coil carries a pointer which either moves over a scale, or is depressed by means of clockwork mechanism to an inking arrange-ment, so printing a mark of its position on a sheet of paper wrapped round a revolving drum. Two scales are provided, one in milli-volts, the other in degrees. The galvanometer is of sufficiently high resistance to permit of the instrument being placed at a considerable distance from the source of heat, without requiring to make allowance for the resistance of the conducting wires. The end of the couple which is farthest from the source of heat must be kept at a constant temperature. The recorder used is the thread recorder. The galvanometer boom turning about its axis is depressed every minute, or half minute, as desired, on to the inked thread whence the instrument derives its name—which is forced

against the paper, leaving a small mark behind on the paper, the ink being renewed by a winding mechanism.

The Féry Radiation Pyrometer.—In the resistance and thermo-electric types of pyrometers just described, the bulb, or the couple must acquire the temperature of the furnace, or blast main or other source of heat. This is often open to objection when temperatures higher than about 1,200° Cent. have to be measured, due to the injury which the instrument is apt to suffer. Hence the reason for the invention of the radiation type of pyrometer by M. Féry, in which design the instrument may be placed at a considerable distance from the furnace, and no part of the instrument is raised temperature of the iron in a Thermit mould, 2,500° Cent., and that of the sun, over 5,000° Cent.

The construction of the Féry radiation pyrometer is shown in Fig. 184. The heat radiations fall upon a concave mirror in the instrument, and are thence reflected to a focus. There is a thermometric couple in this focus, the temperature of which is raised by the radiation falling upon it. The details of the instrument and the methods of use are best given in the words of the English manufacturers of the instrument, the Cambridge Scientific Instrument Co., Ltd. :—

"The complete outfit consists of a telescope and a galvanometer; fixed within the telescope,

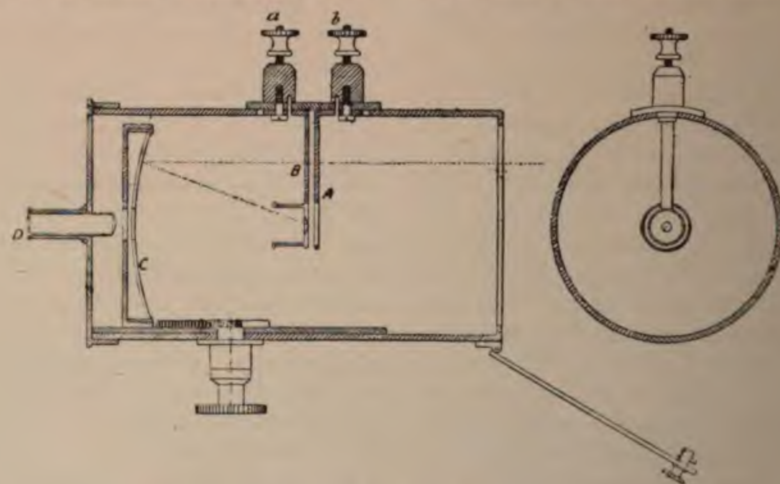


Fig. 184.—Diagram of Féry Radiation Pyrometer.

above the temperature of the air by more than 80° Cent. The advantage of this in taking temperatures of metal in furnaces, and while lying in ladles, of retorts, and other vessels is obvious. Casting temperatures, for example, hitherto judged by the practised eye of the foremen for pouring hot, or dead, or otherwise can be ascertained by simply focussing the pyrometer on the liquid metal. This would be impossible with an ordinary tube pyrometer. It has been found that the reading obtained for the temperature from a stream of molten steel was the same, 1,200° Cent., whether the instrument was set 3 ft. or 60 ft. away. And the same instrument was used for ascertaining the at a point upon its optic axis, is the junction of a copper-constantan thermo-couple arranged in the form of a cross. The two wires are attached to two brass strips A and B which are attached to the terminals, *a*, *b*. The terminals are connected by leads to the galvanometer. The radiation from the hot body under observation falls upon the concave mirror D and is brought to a focus on the copper-constantan couple. To use this apparatus for measuring the temperature of a furnace, an observation hole in the wall of the furnace is sighted through the eyepiece, the image of this hole being brought into coincidence with the thermo-junction. It is essential that the image of

servation hole should slightly overlap nction, which appears to the eye as a disc in the centre of the field of view. adings of the instrument are then inent of the size of the observation hole. nage of the hole is reflected to the eyeby means of two mirrors placed close to ple. These mirrors serve for the adjustof focus; they are so arranged that the of the hole appears to be split in two which only coincide when the focussing ect. The image thus formed upon the n produces a rise of temperature which vn experimentally to be proportional to ount of radiant energy which enters the pe. The junction acquires exactly, and great rapidity, the temperature of the but in no case does its temperature rise e than 80 Centigrade degrees above the heric temperature. The electromotive hich is thus generated is measured by a sensitive galvanometer whose scale is l and figured so as to read temperatures y.

adjustable diaphragm is fitted in front of escope in order that the amount of radialling on the thermo-couple may be varied. measuring high temperatures the dia- partially covers the aperture of the pe, and the temperatures read directly second scale of the galvanometer. The nperature scales ordinarily divided on the ometer are approximately 600° to 1,300° and 0° to 2,000° Cent."

graduation of the galvo-scale is based on s law, which expresses the relation bethe temperature of a body and the amount ant energy which it emits, as follows:—

"The radiant energy emitted by a furnace or black body is proportional to the fourth power of the absolute temperature of the body."

To ensure correct measurement it is only necessary that the image of the hot body should be of sufficient size to overlap the thermo-junction on all sides, and that the hot body should be at least as large in diameter as the mirror of the telescope. It is found in practice that the diameter of the hot body or furnace aperture should roughly measure as many inches as the distance from the hot body to the telescope measures yards, *i.e.*, the aperture should be in diameter about one-fortieth of the distance the pyrometer is away from the hot body. The instrument can be used for the measurement of temperatures from 600° Cent. upwards.

The Féry Absorption Pyrometer.—Another type of Féry instrument is an improved form of the original optical pyrometer of Le Chatelier. It can be used where the radiation instrument cannot be. It comprises a telescope which carries a small comparison lamp attached to one side. The image of its flame is projected on a mirror set at 45° with the axis of the tube and in the principal focus of the telescope. The mirror is silvered only on a narrow vertical strip. The telescope is focussed on the object the temperature of which it is desired to measure, the object being viewed on each side of the silvered strip. A pair of absorbing glass wedges are placed in front of the objective of the telescope, and these move laterally by means of a micrometer screw until the light from the object under observation is made photometrically equal to that emitted by the standard lamp. A table provided converts the readings obtained into degrees Centigrade.

Q

Quadrant.—In geometry is the fourth part of a circle, or 90°. In engineering the swing plate which carries change gears is termed a quadrant plate. The notched plate for reversing, and other levers is also a quadrant plate.

Quadrilateral.—A quadrilateral figure is one bounded by four straight lines. Of the six kinds of quadrilaterals, four (square, rectangle, rhombus, rhomboid) are **Parallelograms**. The remaining two are the **Trapezium**, which has none of its sides parallel, although some of the sides, and some of the angles may be equal to each other, and the **Trapezoid**, which has two of its sides parallel, and some of the sides and the angles may be equal to each other.

Quadruple - Expansion Engines.—*See* **Compounding**, for the principle. These represent the latest stage of compound engines, and they are used successfully on the largest liners. The arrangement of cylinders varies. In the engines of the *Kaiser Wilhelm II.* the high - pressure cylinder is placed above the first intermediate. Alongside is the second intermediate, followed by the low-pressure. In the *Kronprinz Wilhelm* and the *Deutschland* and in the *St Paul* and *St Louis* there are six cylinders. Some dimensions are given below.

St Paul and *St Louis*, six-cylinder, quadruple-expansion engine, four cranks. Two cylinders of 28 in., one of 55 in., one of 77 in., and two of 77 in. Piston stroke, 60 in. Steam pressure, 200 lb. I.H.P. 18,000.

Deutschland, six-cylinder quadruple-expansion, four cranks. Two cylinders of 36·61 in., 73·6 in., 103·9 in., two of 106·3 in. Piston stroke, 72·8 in. Steam pressure, 220 lb. I.H.P. 36,000.

Kronprinz Wilhelm, two sets, six-cylinder, quadruple-expansion, four cranks. Two cylinders of 34·2 in., one of 68·8 in., one of 98·4 in., two of 102·3 in. Piston stroke, 70·8 in. Steam pressure, 213 lb. I.H.P. 36,000.

Kaiser Wilhelm II., four sets, four-cylinder, quadruple-expansion, six cranks. Four cylinders of 37·4 in., four of 49·2 in., four of 74·8 in., four of 112·2 in. Piston stroke, 70·86 in. Steam pressure, 225 lb. I.H.P. 38,000 to 40,000.

Quarry Cranes.—A special type of fixed crane is used in stone quarries. It is a triangular framed crane, comprising post, horizontal jib, and diagonal strut, all of timber. It is pivoted at top and bottom to slew round a circle. The hand gears are carried in cast-iron cheeks bolted to the strut, the chain passing over a fixed pulley at the jib end. It is a dwarfed type of crane suitable for location underground. Ordinary derrick cranes are also used in quarries, and portable hand cranes.

Quart.—The fourth part of a gallon. A quart contains $69\frac{5}{18}$ cub. in., and weighs 2·5 lb. One litre = ·88 quart, and 1 quart = 1·1358 litre.

Quarter Bend.—*See* **Bend Pipes**.

Quartering Machine.—Quartering denotes the operation of boring the crankpin holes in locomotive driving wheels, at right angles with each other, and the quartering machine is a special type evolved for this purpose. The construction includes a bed-plate, on which are mounted two heads, fitted with boring spindles, and point centres for supporting the axle on which the wheels are fastened. The distance from the centre of the spindles to the crankpin centres is adjustable, to suit the throw being dealt with, and the heads as a whole are movable along the bed, to accommodate varying lengths of axles. Fig. 185, Plate XIII., illustrates a quartering machine admitting 7 ft. wheels, and 9 ft. between centres. The treads of the wheels are supported by blocks on adjustable slides on the bed, so that they are quite rigid during the boring operation. Cranks from 6 in. to 13 in. radius can be dealt with by the boring spindles, which are adjust-

ertically, the other horizontally; the
eing effected by belt pulleys, bevel
worm gear, the worms being made
so that the lateral position of the
des does not interfere with the drive.
dle can be fed by hand, operating
spur gear, by which a pinion drives
on the body of a sleeve encircling
The self-acting feed is arranged
rom spur wheels next to the main
orm wheels, thence to the shafts of
wheels which are employed for hand

ter - Twist
See **Belting**.

:.—Quartz is
d silica or
xide, SiO_2. It
ific gravity of
harder than
ding seventh
scale. It is
used as a
for glass in
Coloured by
it goes under
of amethyst,
, and occi-
phire and em-
artz veins are
rich in gold.
ds of quartz
weight of 50
square inch.
ads are made
g quartz in
drogen blow
d drawing it
ng filaments.

Truss.—*See*

—The term signifies a radius which
latively to other radii. Thus a quick
ne which is more convex than a flat
quick curve similarly.

ime.—Calcium monoxide, CaO, caus-
or **Lime**, is obtained by heating
te of Lime (limestone) in kilns, the
cid escaping.

Return.—Relates to the return movement of a machine table during the non-cutting stroke, and by which the time lost thereby is lessened. There are several methods by which this is effected. The simplest, and

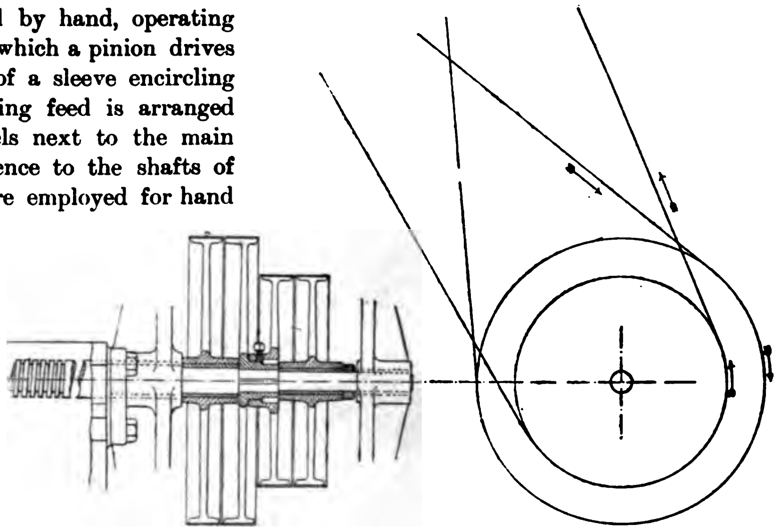


Fig. 186.—Quick Return.

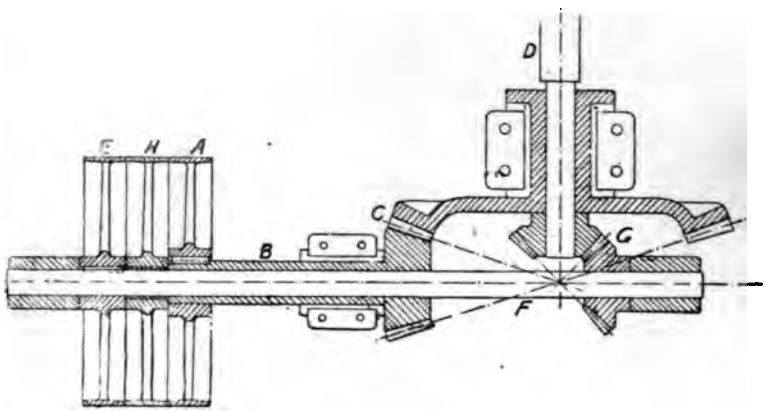


Fig. 187.—Quick Return.

one which is very commonly adopted, is to have two sets of belt pulleys, Fig. 186; a large pair, fast and loose for the driving, with a crossed belt, and another pair—smaller, driven with open belt for reversal. Another device is that of a pair of bevel wheels, larger and smaller in the proportion required for driving and return, Fig. 187; the pinions being driven, one by a sleeve, the other by a shaft passing through

the sleeve from the usual combination of three pulleys, two fast, flanking a central loose one. In Fig. 187, A is a fast pulley on the sleeve B, driving gears C to rack pinion shaft, or the screw D. E, a fast pulley, drives the shaft F and mitres G to D. The fast pulleys are driven by an open belt, and when this is shifted on to either driving pulley the middle pulley H runs loose. This has been used to a considerable extent on planing machines. In the regular standard planing machine drive as used alternatively to Fig. 186, the arrangements are as represented in the diagrams, Fig. 188. In each a single open belt is used, driving a pulley on a sleeve, the inner one *a* in the figures, also a pulley keyed on a shaft which goes through the sleeve, the outer one *b* in the figures; and a central loose pulley, *c*, when the machine is standing idle, or at the instant of reversal of the belt. The arrows show the direction of rotation of the gears corresponding with forward driving and quick return, the gears lettered *f* being for driving, those *r* for return, R indicating the rack. In Fig. 188 (A), the outer pulley *b* on the shaft *s* drives the wheels marked *f*, as indicated by the arrows in full lines, for cutting. The inner pulley *a* on the sleeve S drives the wheels marked *r*, in the direction indicated by the dotted arrows, for return. At (B) the arrangement is identical, only the gears are located snugly to bring all of them except the rack pinion outside the bed. In (C) the pulley *b* on shaft *s* drives the gears marked *f*, one being an idler, and the pulley *a* on the sleeve S the gears *r*.

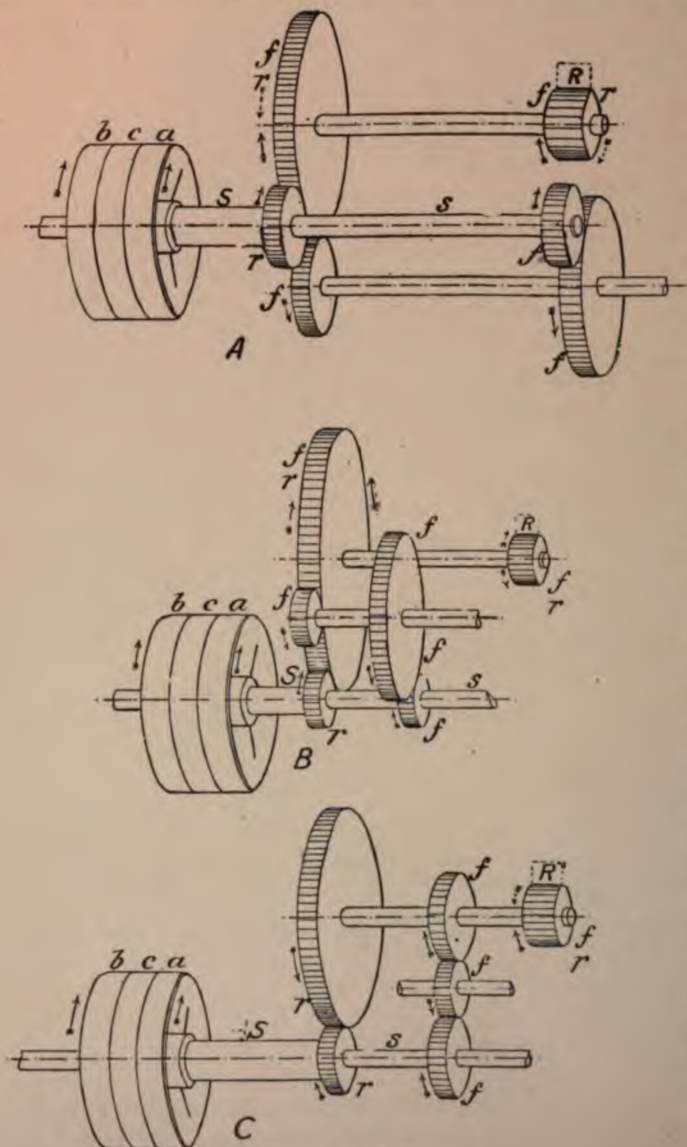
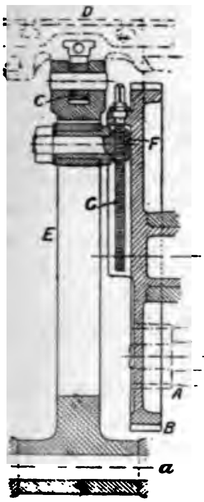


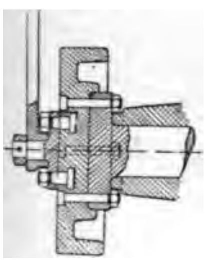
Fig. 188.—Quick Return.

It is seen that assuming the pinions are of equal size, the difference in the rate of driving and return is due to the proportion which the diameter of the large wheel bears to that of the pinions. The difference between the two sets of gears, (A) and (B), is simply that of arrangement. In the first case half the wheels are situated within the bed, as was the common practice a few years since. It involves running the table right back when inspection or repairs have to be done. For this reason the arrange-

of (B) is generally adopted, in which the the rack pinion excepted, are all situated le the bed. A different design is shown in ie result being the same.



quick return is used on shaping machines hich the tool is reciprocated by a rigid Shapers having a stroke of 6 in. or are not usually so fitted, but those with



es of about 8 in. and over are. In ink planing machines having table move- s from say 1 ft. 6 in. to 3 ft., a rigid lever d with a link type of quick return.

A quick return of this kind applied to planing machines is illustrated in Fig. 189. The pinion A drives the wheel B, with uniform rate of rotation. But the connecting rod C drives

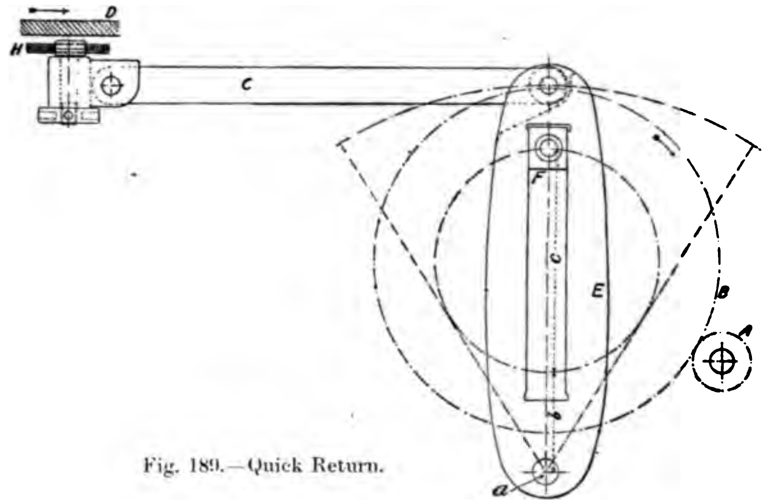


Fig. 189.—Quick Return.

the table D, slowly on the cutting stroke in the direction of the arrow, and rapidly during the opposite or return stroke. This is effected through the link E, which is pivoted to the

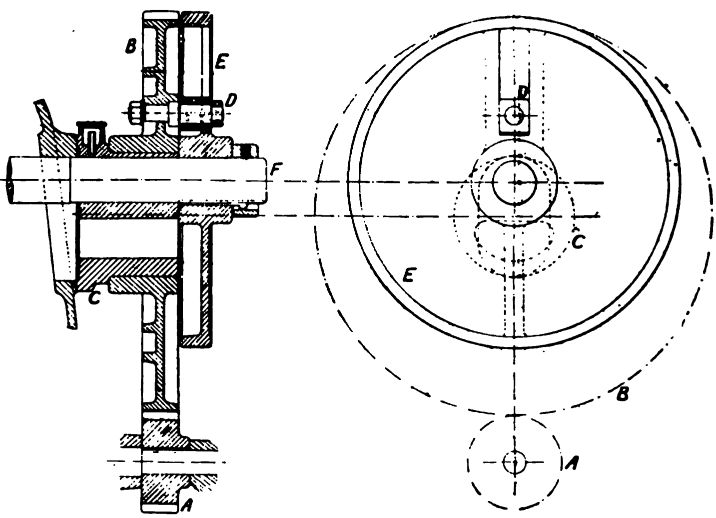


Fig. 190.—Quick Return.

machine framing at a, and which receives a rocking movement round a from the rotation of the wheel B. This is effected by the connection of the die block F with B, to which it

is attached. The connection is made by a screw G, by which, too, the radial position of the boss F in relation to the wheel B can be altered, and the length of stroke. In the position shown the proportion of cutting and return stroke is as the radius *b* is to *c*. Bringing the block F nearer to the centre of the wheel would alter this rotation. Identical mechanism is put on many, probably most, shaping machines.

lever, and its eccentric position in relation to the wheel brings the centre of attachment of the connecting rod nearer to and farther from the centre of the wheel in the course of the rotation of the latter. The driving is effected by a pin in the face of the wheel, which enters and slides in a slot in the crank in the end opposite to the point of attachment of the connecting rod. The latter is in a slot with a

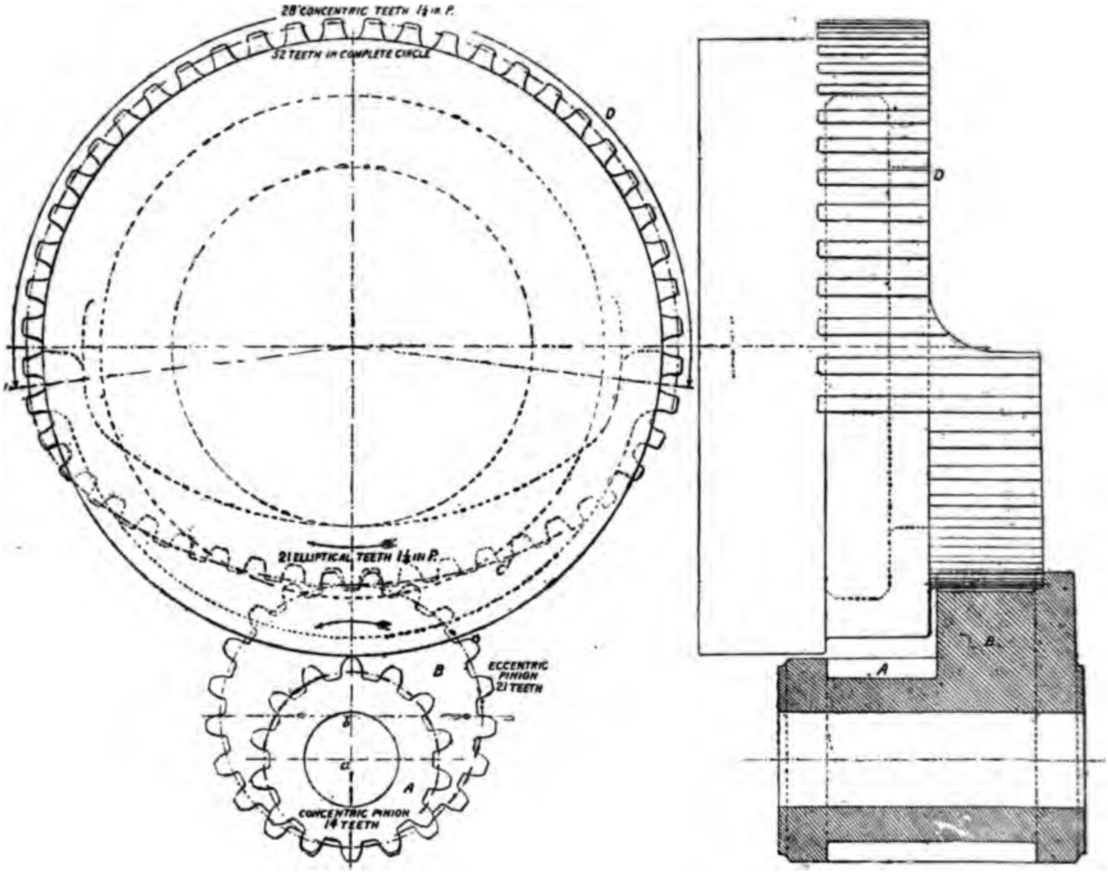


Fig. 191.—Quick Return.

Another design of quick return due to Whitworth is not so often used, as not being quite so simple as the link design just shown. As before, a spur wheel is driven by a pinion at a uniform rate. The wheel rotates on a sleeve large enough to permit of the passage of a shaft set eccentrically therein, which shaft carries a slotted crank from which the connecting rod to the table receives its motion. The crank is a

screw and die block to permit of altering the length of stroke.

Another form of quick return which has been applied to some small shapers is more direct in action, though not so compact. The die block, driven by a pin fixed in the face of the spur wheel without any range of adjustment, slides in the slot of a long lever pivoted in the framing of the machine, between the wheel below and

ram above. The top end of the lever, e, moves at different rates for cutting urn, because the die block is farther om the pivot on which the lever is centred the cutting, than it is during the return As the top end of the lever moves in f a circle, an oscillating connecting link ts its movement to the tool ram.

methods of producing quick return, th a link, and that with a slotted crank, lied to slotting machines. Fig. 190 shows er as applied to one of the Greenwood ey machines. In this, the pinion A the wheel B which runs loosely on the c. A pin and die block D connects it crank disc E, by which the shaft F is and connected to the slotting arm. he die block D is in the position shown, arest the centre of the shaft F, and is re moving quickly. On the opposite side liameter its movement will be slowest.

Another device is that of elliptical gears, shown in one of its designs by Fig. 191 as fitted by Messrs Greenwood & Batley to some of their slotting machines. A pair of spur pinions are set eccentrically, and above are two segmental gears in one. One portion has its pitch line in an arc of a circle, the other as a portion of an ellipse. As one pinion comes out of gear with its segment, the other engages with the other segment, so providing the elements of slow cutting and quick return due to the difference in radii.

Quicksilver.—*See* **Mercury**.

Quill. — A hollow shaft through which another shaft passes, so providing for two distinct motions around one axis.

Quintal.—A metric weight equal to 100 kilograms, or 10 myriagrams, and therefore containing 100,000 grams. Its British equivalent is 1 cwt. 3 qrs. 24 lb. 7 oz. 6·3 drams; or 220·49 lb.

R

Rack.—A straight gear which is driven by, or drives a wheel or pinion. The rack has an interest besides, due to its practical application in the fact that it is the basis of all gear wheel tooth curves. Being regarded as a wheel of infinite radius, its tooth shapes are made the basis of generation for the teeth of all wheels of the same pitch, precisely as though these teeth were cut or moulded by the rack, the wheel blanks rotating as if in engagement with the rack teeth. The angle of the rack teeth determines the curves of the wheel teeth, and the angle of 75° is that usually taken, the objection to a higher degree of obliquity being the steep diagonal thrust between the teeth. For simplicity, also, the rack teeth have straight flanks in the involute system, so generating single curve wheel teeth. An advantage of the generating machines in which gears are cut on the basis of the rack is that every wheel has absolutely correct tooth forms, which is not the case when a set of cutters is used.

The Forms of Racks.—These may have teeth straight across, or square, as when working with spur pinions and wheels, which is the commonest form. When the teeth are set diagonally—as in *spiral* racks—they may be designed for engagement with a spiral gear, or with a worm gear. A spiral wheel will also work with a straight rack, in which case it is better to make the rack of concave section to hug the screw like a worm wheel. Such a rack is a worm wheel of infinite radius.

Manufacture of Racks.—These are cast from patterns, or more generally cut on an ordinary machine, or on some milling machines. For making quantities there are also special machines. Also a number of racks, from half a dozen to a dozen, may be arranged side by side and cut at one setting. Further, instead of a single cutter, from three to a dozen can be used operating at once across a number of racks.

Racking Gear.—A term which denotes the mechanism by which the block carriage or jenny of a long armed crane is travelled to and fro along the horizontal jib. It comprises the chains, or wire ropes, and their pulleys, which may be actuated by any agencies applied to cranes, as steam, or electricity.

Rack Locomotive.—A locomotive designed for working up the steep gradients of mountain railways, for which the adhesion of smooth rails would be insufficient. There are two systems; one in which the teeth of the rack stand in a horizontal plane, the spur wheels gearing with it having their axles horizontal; the other in which the teeth are vertical, and the wheels have their axes vertical. The racks in this case are in pairs, one on each side of a central rack rail. It was adopted on the Mount Pilatus Railway, because when the ordinary rack was tested on a length of line the pinion rose out of gear when the full work was put on it. This was due to the great incline, which is in some parts 480 per 1,000, or 1 in 2·08, by which the action of gravity is much diminished. The steepest parts of the Vitznau-Rigi line do not exceed 250 per 1,000, or 1 in 4, and here the ordinary rack is suitable.

A system which is not in use now was the endless screw, and triangular rack. In this a drum revolved with the wheel axles and geared into Λ shaped teeth fixed to the sleepers between the rails. On the trial trip the screw mounted the rack, and the train ran down, with fatal results.

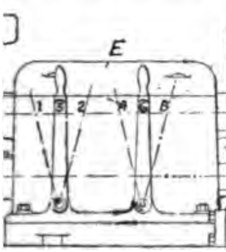
Many rack locomotives are of combined adhesion and rack type. There is economy in this design in mountain ranges when speed is of little account, because the cost of construction is often greatly lessened. On such lines it is usual to lay out the gradients to be worked by adhesion from 2½ to 5 per cent., and those for rack working up to 10 or 12 per cent. The following give particulars of com-

sion and rack locomotives used for Pass Railway. They measure 8·6 28·2 feet in length over all; and 2 5·56 feet in width. They have three nesion wheels, two pinion axles, and railing axle. The total weight is pty, and 30 tons full, which includes water, and 4 tons of fuel. The ve two outside cylinders for adhe- les for which are coupled; and two for the pinions. The following are dimensions of the engines:—

; surface -	- 70 sq. m.	735 sq. ft.
- - -	- 1·26 sq. m.	13·56 sq. ft.
ssure -	- 12 atmos.	176 lb. per sq. in.
esion cylinders -	34 cm.	13·37 in.
nesion pistons	- 45 cm.	17·16 in.
ion cylinders	- 30 cm.	11·80 in.
ion pistons	- 36 cm.	14·16 in.
esion wheels	- 80 cm.	31·40 in.
ion wheels	- 69 cm.	27·14 in.
n wheel base	- 4·35 m.	14·26 ft.
of adhesion driv- (1·17 × 2) -	- 2·34 m.	7·67 ft.
of pinions -	- 1·17 m.	3·84 ft.
d per pair of wheels -	- 8 tons.	8 tons.

Axle Box. — A originally to Mr 1863, for radiating ents of leading and les of locomotives rves, to avoid the gid axles on a long . It is not used having been super- e bogie truck.

al boxes are free to ally in a curve of s, the centre of the centre of the adjacent, and they have a range of movement of about 4 in. or 5 in., which movement is cushioned by springs. In Mr Webb's design coiled spiral springs in the centre of a spring frame act on the boxes through rods around which the springs are coiled. The spring frame and the guides are rigid with the framework of the engine, and except for their capacity for radial movement the axle boxes and journals are of the ordinary kind. When the engine enters a curve, say to the right hand, the flanges of the leading wheels draw the boxes to the right. The axle on the right-hand side is thus brought nearer to the driving wheel behind it. The trailing wheels take on a similar position, and thus the leading and trailing axles become radii of the curves they are running on, with the wheel flanges tangential to the curves. The axle



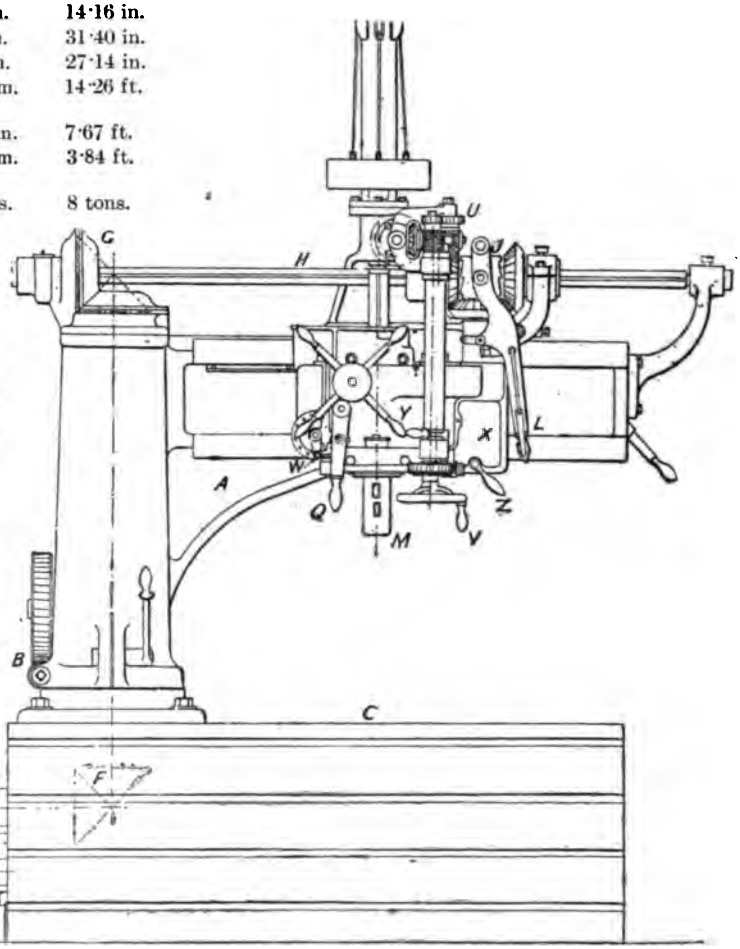


Fig. 192.—Radial Drilling Machine. (John Stirk & Sons, Ltd.)

boxes move freely in the lateral direction, accommodating themselves to the varying curves of the rails.

Radial Drilling Machine.—This is the most useful type of drilling machine for general

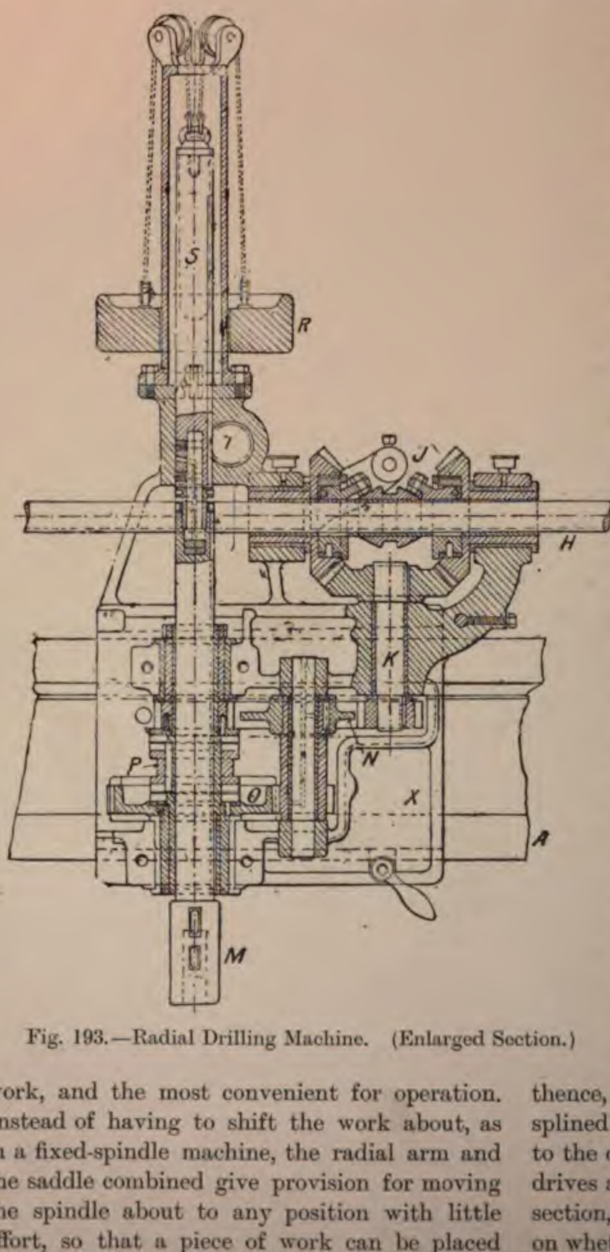


Fig. 193.—Radial Drilling Machine. (Enlarged Section.)

work, and the most convenient for operation. Instead of having to shift the work about, as in a fixed-spindle machine, the radial arm and the saddle combined give provision for moving the spindle about to any position with little effort, so that a piece of work can be placed on the table, or the plate, and a number of holes drilled in it without further setting. A larger capacity or swing can also be obtained by the use of a projecting arm, so that objects too bulky to be put on an ordinary pillar drill are accommodated on a radial. There are three main types of radial machines: (1) Those with the arm cast integral with a socket fitting over a pillar, on which the socket is revolved to swing the arm; (2) those with trunnions standing at right angles to the arm, and fitted in divided bearings on a vertically adjustable slide; and (3) those in which a large turned pillar receives the arm, fitting by a divided socket, providing for a complete turn around the pillar. The drilling spindle in every case is carried in a saddle, movable across the face of the arm; sometimes provision is incorporated for angling the spindle, but it is usually considered preferable to use an angular table, that is one which can be tilted by worm gear to set the work to any angle. Machines of class (2) are constructed to go against a wall when this is desirable, the casting forming the trunnion bearings fitting direct on to the wall.

Fig. 192 gives a side elevation of a 3 ft. 6 in. high-speed radial drill, of the class first mentioned above; the arm A is cast in one with a socket fitting over an internal pillar, an elevation of 12 in. being effected by worm gear B, and rack. The box base C has tee-slots on the top and sides. The driving is effected through the fast and loose pulleys at D, in connection with the gear box E, by which nine changes are produced. A shaft from the box passes along to mitre gears F, driving a central vertical shaft within the pillar, and thence, through mitre gears G at the top to a splined shaft H by which the motion is conveyed to the drill spindle. A nest of bevel gears at J drives a short vertical shaft K (see the enlarged section, Fig. 193) in either direction, depending on whether the clutch to right or left is thrown in, by moving the lever L. A friction clutch is represented in Fig. 193, but a positive drive

ined in the later machines by claw s, *see* Fig. 192.

n K, spur gears transmit the power to ill spindle M. There are two sets of N and O, N being single—with an idler, double gear, so affording two ratios, ng to the position of the claw clutch ed by the handle Q, engaging with teeth faces of the spurs, which have sleeves ing the spindle so that there is no side on the latter.

spindle is counterbalanced by a neat ement which includes an annular weight ng three chains passing up over pulleys wn through the hollow casing to an eye- the top of the spindle extension S. ethod gives a perfectly central pull, and ight is not lop-sided as when it is placed side of the spindle. The portion S has a one side, through which the down-feed ted, S pressing on anti-friction washers in ndle M. The rack is engaged by a pinion the latter is rotated by a train of gears ctuated by the hand-wheel V, turning at either a worm gear for a slow motion, or d bevel gears at U for a quick motion; ndle of V is mounted in an eccentric which can be partly revolved by a handle. ject of this is to engage either of these s and also to throw a worm wheel, seen ove V, into engagement with a worm be-, driven from a nest of spur gears, con- from the spindle gear; four changes of e obtained by moving the small lever W quadrant. The saddle X carrying all this ism is racked along the arm by a star Y, and locked in position by Z, which p a pad pressing on the edge of the arm. take-up strip bears on the top edge, and sted by a short rack, and a pinion, the eing locked by a lateral screw.

ils of the gear box are given in Fig. 194. ction shows the fast and loose pulleys, st-named, A, driving a sleeve on which se pulley runs. This sleeve is carried the box, and has keyed on it spur wheels nd P, engaging with loose wheels D, E, on a shaft F, with gears G and H fitted and gear S keyed to F, and meshing with J, K, and R, on a shaft running freely inside the driving sleeve. The end of this shaft is provided with a key to take the mitre gear on the end driving the vertical shaft within the pillar. Clutches L and M sliding on bushes keyed to the shaft F enable the respective gears to become engaged. When the clutches are in mid-position, the slower running gears Q and R come into operation. These gears carry a ratchet arrangement, as shown in the enlarged detail, Fig. 194. The clutch teeth on wheels D E, G and H are of steel, screwed on. The handles, N, O, fitted with spring locking plungers, can each be set in three positions and a variety of changes are produced, according to the relative positions. The speed chart below gives the results obtained and is to be read in conjunction with the drawing, Fig. 192.

Speed Chart of Radial Drill.

Positions of Levers.	Speeds of Spindle.	
	Single Gear.	Double Gear.
1 A - - -	680	104·0
2 A - - -	568	86·5
3 A - - -	467	71·5
1 B - - -	370	56·1
2 B - - -	307	46·5
3 B - - -	254	38·6
1 C - - -	194	29·4
2 C - - -	161	24·4
3 C - - -	133	20·3

A machine of class (2) is shown in Fig. 195. Here the pillar A, bolted to the base-plate B, provided with box table C, carries a slide D, having a split bearing at the bottom (for clamping), and a capped bearing at the top, to take the two trunnions of the arm E, fitted with ball bearings. Fast and loose pulleys at F drive the cone G, belted to another H; the latter connects either direct to mitre gears at J, for quick speeds, or through intermediate back gears situated under the casing at K, and put into and out of operation by a handle L. The raising and lowering of the slide D is effected by gears worked from the shaft of H, driving to a

nest of bevel wheels at M, rotating a vertical screw which works in a nut on the slide D. The lever N throws in the clutch for driving this screw.

The short vertical shaft which is driven by the gears at J actuates mitre wheels at O, turning a horizontal shaft P, on which a sliding bevel Q drives another bevel on a short vertical

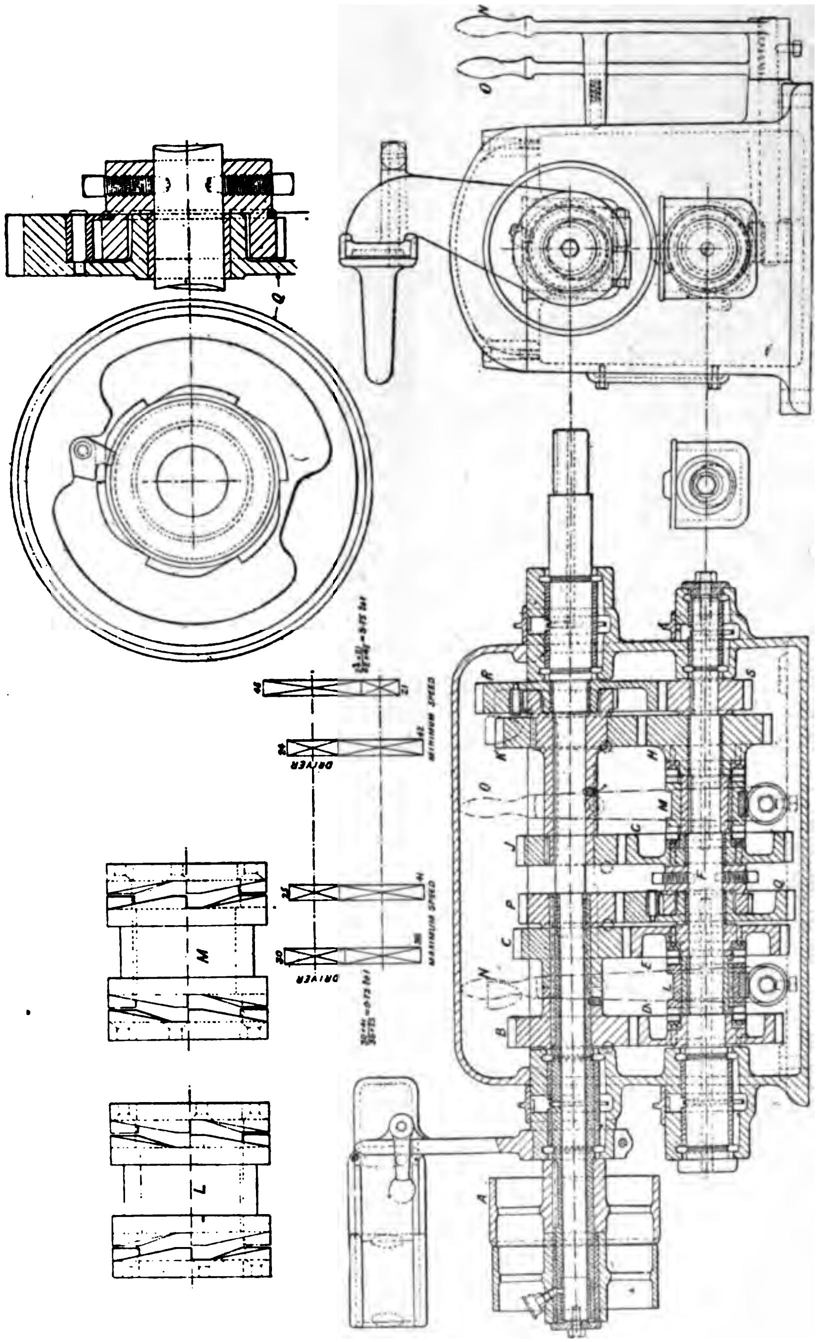


Fig. 194.—Gear Box, Radial Drilling Machine. (John Stirk & Sons, Ltd.)

shaft on which is a pinion, engaging with the spur wheel R, on a sleeve surrounding, and driving the drill spindle S. Belt pulleys T drive the feed, through bevel gears to the nest of spurs at U, any pair of which can be engaged by an internal sliding key operated by the lever V; the gears then drive a vertical shaft connected to a worm and spur gear, which racks down a sleeve encircling the spindle S in its lower bearing; hand feed can also be imparted

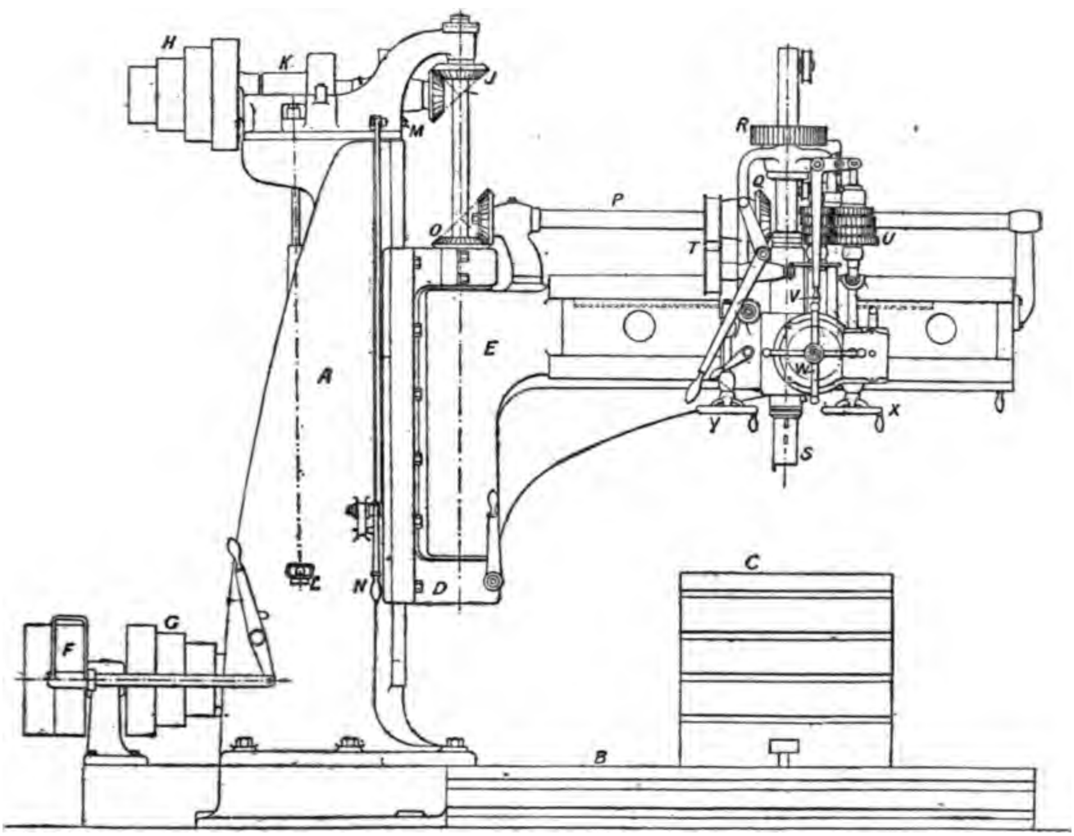


Fig. 195.—Radial Drilling Machine. (Tangyes, Ltd.)

quickly by the cross handle W, or slowly by hand-wheel X. The saddle is racked along the rail by the hand-wheel Y, turning worm gear which rotates the rack pinion. The clamping is done by a small lever above Y.

An all-round or universal radial machine of class (3), having a circular pillar is shown in Fig. 196, Plate XIV. The column is bored out inside to fit over a post, which is fixed to the base-plate, and the column may be clamped firmly by means of bolts passing through its foot, or revolved on releasing these. The radial arm is held on the column by a split sleeve, which may be adjusted up and down by a screw, and the arm itself fits by a circular facing to this sleeve, so that it may be angled to drill holes other than vertical. The driving of the machine takes place from an electric motor mounted on the top of the column, with its armature shaft standing vertically, and rotating a pinion at the top, turning a spur gear which drives a long vertical shaft passing down to the foot. A pair of bevel gears transmit the motion at right angles to a four-step cone pulley in bearings on the sleeve, and a belt drives another cone below, which is provided with back gear to give an ample range of speeds. The power is conveyed to a shaft lying within the radial arm through gears, and so to the drill spindle. The saddle

of the latter can be moved along the arm, and its down feeds are produced either by hand or power. A swivelling table, seen beyond the arm, is used for certain classes of angular drilling.

Radian.—When an angle is subtended by an arc of the same length as the radius of the circle this angle is called a radian. There are 2π radians in any circle. An angle may be expressed in radians by dividing the arc by the radius.

Radiation.—*See* **Heat—Transmission of.**

Radium.—Except in its romantic aspect, radium does not concern the engineer. Yet its power of evolving energy unceasingly is so marvellous that, should it ever be available in large quantities, it might prove of vast interest in engineering. To the chemical engineer radium is the most fascinating in the long list of elements. It has ruthlessly uprooted old established theories of matter, shattered the ideas of older students, and left them as it were with no bearings. To have declared a generation ago that elements could change from one to another, or that the atom was far from being the ultimate form of matter, would have been rankest heresy. Now we know that the alchemists who, groping ignorantly in the dark, sought to change coarse metals into fine gold, were not so mad as we imagined them. It has now been definitely proved that uranium yields radium, which in turn, as Sir William Ramsay has shown, yields helium. The emanations of heat and light are due to the decomposition of the atoms. Sir Oliver Lodge has stated that 100,000 electrons could lie in the diameter of an atom, and that the disproportion in size between the electron and the atom is greater than that existing between the earth and the sun. The break-up of the atom and the discharge of the electrically charged electrons at a speed equal to that of light, explains the radio-activity of this element. The rays given off by this disintegration are named the alpha, beta, and gamma rays. The alpha rays are material particles, and are regarded by Rutherford as atoms of helium, in a state of great activity and excitement. The beta rays are unit charges of negative electricity travelling at about 60,000 miles a second. The gamma rays are similar to the Röntgen rays. As regards the estimation of the energy emitted by radium, Curie and Laborde calculated that 1 gramme evolved enough heat per hour to raise its own weight of water from freezing to boiling point every hour. A pound of radium would supply energy sufficient to lift two-thirds of a pound 1 foot high per second for a thousand years. M. Curie once stated that it would probably mean death to enter a room containing only half a pound. The principal source of radium is pitchblende — composed fundamentally of uranium oxides—and a ton of this produces only 1 gramme of radium, costing over £400.

Radius.—The radius is half the diameter of a circle, or the distance from the centre to any point in the circumference. In the same circle, or in equal circles, all radii are equal. Twice the radius, multiplied by 3·1416, gives the circumference; and the radius squared, multiplied by 3·1416, gives the area of a circle.

In trigonometry the radius is the whole sine (or sine of 90°). *See* **Circle.**

Rail Bender.—An appliance which is used for bending rails to curves. It embodies two claw supports for the rail, situated from 16 in. to 30 in. apart, and a ram situated midway between, by which pressure is applied. The ram is either operated by a screw, or for heavy rails by hydraulic pressure, the mechanism being on the principle of the hydraulic jack. Benders generally have the screw or ram vertical, but in some hydraulic machines the ram is horizontal, and the machine portable on wheels, as for tram-line service.

Fig. 197 illustrates a screw rail bender, or *Jim Crow*, by Youngs, of Birmingham. The body and the screw are of hammered scrap iron. A steel swivelling shoe remains unmoved while the screw is turned. It is made in a large number of sizes, with screws from 1½ in. to 3 in. diameter, to bend rails from 14 lb. to 90 lb. per yard, as well as shafting, tubes, &c.

Fig. 198 illustrates a 15-ton hydraulic rail bender by Messrs Youngs. The bow is of hammered scrap iron, the ram of steel, the cistern is of malleable cast iron, the pump and valves of gun-metal screwed into the bow. The mechanism of the lever, the stop-valve, &c., is

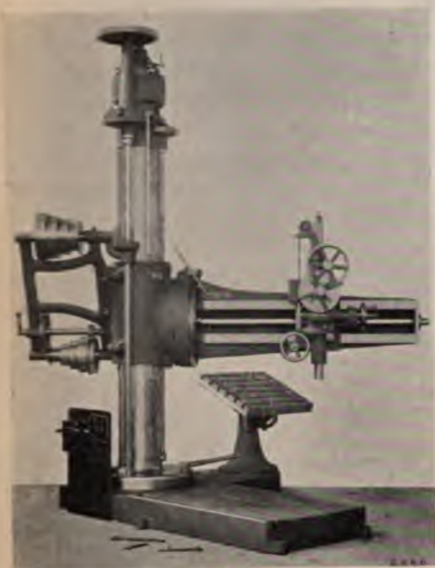


Fig. 196.—Radial Drilling Machine.
(The Niles-Bement-Pond Co.)

Fig. 202.—Reamer at Work in Boring Mill.
(Ludw. Loewe & Co., Ltd.)

Fig. 216.—Wall Jib Crane with Suspended Riveter.

Fig. 217.—Single-Rail Riveting Crane.

(Henry Berry & Co., Ltd.)

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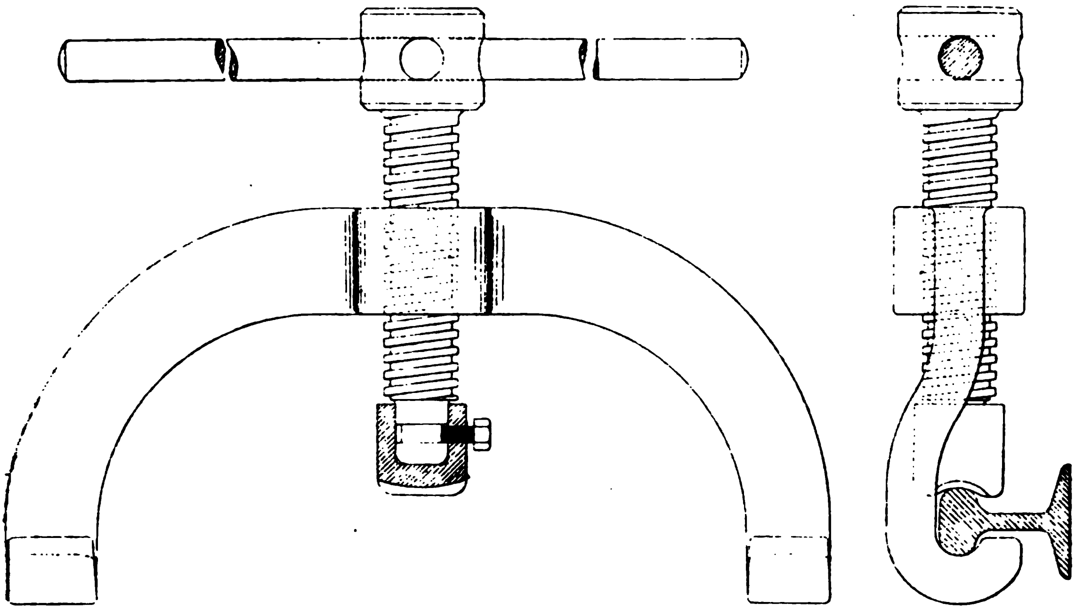


Fig. 197.—Screw Rail Bender.

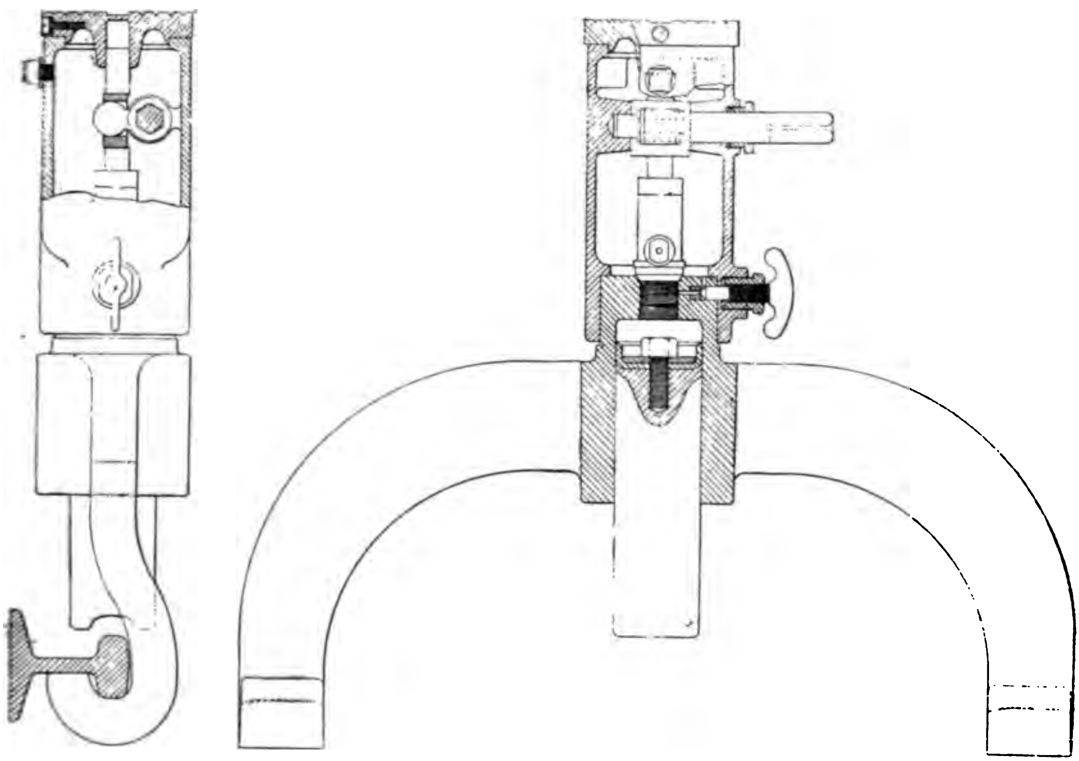


Fig. 198.—Hydraulic Rail Bender.

identical with that illustrated of Youngs' ship jack, in Vol. VI., page 28, Fig. 20.

Rail Clips.—A device employed for the purpose of holding portable cranes down to the rails when hoisting is being done across the track, being an alternative to **Blocking Girders**, though both are sometimes fitted to the same crane to be used as alternatives. The rail clips are suspended from a piece of plate bolted to the top of the crane truck. The suspension is from the eye of a loop, the upper end of which is secured to the plate with a long screw and nut, which affords the means of raising the clips clear of the rail when not in use. The clips fit loosely in the loop, and are tightened around the rail by a ring or coupler embracing the clips.

Rail Drilling Machine.—This may be either fixed or portable. In the fixed machines there are two or more spindles, the centres of which can be adjusted for different pitchings, and the holes are put through simultaneously. In the portable machines, for out-door use, hand mechanism is used for driving, generally with a ratchet brace, and special cranked clamps are made to hook around the rails at two positions, and so take the thrust of the drill.

Rail Lifter.—An appliance which comprises a stand that serves for bearings for a long screw, turned by a double-ended lever by hand, and lifting a broad foot standing out from the bottom, which is inserted underneath the rail to be lifted.

Rail Mill.—A rolling mill which resembles the mills used for rolling bars or sectional forms, but having rolls suitably turned. It includes three mills; the cogging for reducing the ingots, the roughing, and the finishing. The cogging mill reduces the ingot in large rolls, which range from 28 in. to 45 in. in diameter. The alternative is the steam hammer. But cogging by this method, which dates from the early days of the Bessemer process, has generally been superseded in all but the smallest mills. The cogging plant costs much more than the hammer, but the output is greater, and the cost for labour less.

The rail mill is a three-high reversing mill, having long superseded the pull-over mill. The rolls measure about 26 in. in diameter, and the principal bulk of the rail lies in the bottom, and the middle groove only, the upper faces without edges being formed in the top roll, and in the lower portion of the middle roll. The passes are of the closed type, and the rail has to be turned over at every pass. In the American mills the disposition of the grooves is such that the rails have not to be turned over at all. As the rails would tighten in their deep grooves, guards are fitted next the bottom and middle rolls on opposite sides, to release, or *peel* the rails as they issue from the grooves.

A modern rail mill will turn out 4,000 tons a week. Rolls have to be checked and re-dressed, or changed about once in every three shifts. Rails are cut to length while hot, and cooled on the hot bed. When cold they are trimmed to length with inserted tooth milling cutters, and are subsequently drilled and straightened.

Rails.—The question of the durability of rails is the most important one, by reason of the expenses of renewal, and the large quantities made annually. So much difference of opinion exists in regard to the proper chemical constitution of rails that many companies insist on physical tests only. The two tables given below represent typical compositions:—

GREAT WESTERN RAILWAY.

	Per Cent.
Carbon from	·40 to ·50
Silicon ,,	·10 ,, ·06
Manganese ,,	·05 ,, ·85
Sulphur, maximum	·08
Phosphorus ,,	·08

LONDON AND NORTH-WESTERN RAILWAY.

	Bessemer, Acid.	Siemens-Martin, Acid.
Carbon	·20 to ·40	·25 to ·50
Silicon	trace ,, ·10	·01 ,, ·25
Sulphur	·01 ,, ·10	·05 ,, ·10
Phosphorus	·01 ,, ·10	·05 ,, ·15
Manganese	·25 ,, 1·25	.25 ,, 1·25
Iron	99·53 ,, 98·05	99·39 ,, 97·75

The main desideratum in a rail is that it shall be as hard as possible consistent with safety. How that degree of hardness shall be secured is answered differently by different authorities. It may be increased by doing mechanical work upon the rail, which was the practice in the early days of the Bessemer pro-

cess, when ingots were hammered instead of being cogged, and when the rolling mills ran at slower speeds than they do now. In the American mills, less time, from various causes, is occupied in rolling rails than in the English, and the rails do not wear so well as the older ones did. It has been stipulated that the last pass shall be rolled at a temperature of about 200° Fahr. less than has been the usual practice, solely to impart a finer grain and increased hardness to the rail. Mr Sandberg's paper on "Steel Rails," read before the Institution of Mechanical Engineers in 1890, contains all that can well be said on the subject. He collated and tabulated a large amount of data on the effects of carbon, silicon, phosphorus, manganese, and sulphur on the transverse and tensile strength and hardness of rails. He strenuously opposed the dangerous tendency to fracture in over-hardened rails. He concluded that hardening by silicon was of little consequence by comparison with that effected by carbon, and phosphorus. Phosphorus, while hardening, makes a steel brittle, and should not exceed one-tenth of 1 per cent. Carbon may range up to 0·40 per cent., silicon 0·10 per cent., manganese from 0·75 to 1·0 per cent. *See also* **Permanent Way.**

As the rail comes from the rolls it is fairly straight, but curves in cooling. Cambering is sometimes practised; that is, the rail is curved in the contrary direction to that which it will take in cooling. The somewhat rude process of straightening is thus avoided, or its amount lessened.

To roll a rail weighing say 80 lb. per yard, an ingot having a cross section of about 15 in. square would be taken and rolled, passing through the rolls some twenty-eight times without reheating. This re-rolling consolidates and improves the quality of the steel, both as regards strength and toughness in an enormous degree. Moreover the mere stretching of steel greatly increases the strength of the attenuated section. Lord Armstrong once mentioned a case where the stretching of a piece of steel from a welded gun coil increased the strength from a little over that of wrought iron (say 20 or 22 tons) to 85 tons per sq. in. measured on the attenuated section.

The present cost of steel rails is about £7 a ton, and the value of the old material for remelting is a considerable proportion of the original cost. It is this cheapness which renders the use of heavy rails economical by comparison with the cost of the old piled rails of wrought iron, and of the steel rails of a few years since.

Rail Sawing Machine.—The fixed cold sawing machines are employed for cutting off rails in the shops, singly, or in a pile. For parting off the rails out of doors, portable types are used, the most common being that of a circular saw, mounted on a spindle in a portable frame which is bolted to the rail; the saw blade is revolved by means of a toothed wheel engaging directly in the gullets of the teeth, which are cut deeply for the purpose; supplementary gearing connected from a pair of handles affords ample power for driving. The saw and driving gears feed down simultaneously as the cut progresses.

Rail Straightener. — An appliance for taking the slight kinks and curves out of rails just previous to laying them in place. It is portable, on smooth wheels, or on flanged wheels to suit gauge, with a frame on which the rail and the squeezing apparatus is carried. A strong cast-iron cross has a slot in one of its arms, in which two adjustable blocks carry the rail. They are cut to fit the rail, and the centres are adjustable to suit any length of rail that wants correction up to about 3 ft. 6 in. maximum. Pressure is applied by a screw or by an hydraulic ram. The same appliance can be used for bending rails. *See* **Rail Bender.**

It is necessary to straighten rails before laying them, because they curve or camber in cooling, apart from accidental bendings. The thicker portion of the rail—the head, cooling last, becomes concave. The greater the difference in the head and the foot, the more the curvature. In flange rails it will sometimes amount to several inches out of straight.

Railway.—*See* various heads, such as **Locomotive Engine, Permanent Way, Rails, Steam Brake, Vacuum Brake,** &c.

Raising.—A process by which works in sheet metal are worked into hollow forms, either by spinning, in which pressure alone

is exercised, or by hammering. Only metals which are highly ductile and malleable will yield to such treatment, as it is essential that the particles shall glide over each other. A process of thinning or thickening goes on in raising, the amount of which varies with the shapes of objects. Obviously in producing a hemispherical object, or a cylinder with a solid end from a disc of metal, the reduction in diameter is very great, and thickening must take place at the edges. Also, however ductile a metal, frequent annealings become necessary, otherwise it would fracture under the severe treatment of hammering. The work of raising is accomplished by a judicious selection of solid, and hollow blows delivered on the sheet. A *solid blow* is one that is given on the sheet lying in close opposition to a supporting block or anvil. A *hollow blow* is one to which there is no direct opposition offered, the portion of the sheet on which it is dealt being away from contact with an anvil. A solid blow must always thin the part of the sheet on which it is delivered. A hollow blow would have the same effect if the sheet were stretched by it, but if the sheet were thrown up to occupy a smaller space the effect would be to thicken it. As the work has to be accomplished in detail, this is the reason why it is done in a succession of narrow flutes or wrinkles which are afterwards obliterated by **Razing**.

Rake.—*See* **Angles of Cutting Tools.**

Rakes.—These, usually drawn by a horse, are employed for collecting material that has been mowed and is lying broadcast on the ground. The rake consists of a line of curved prongs the points of which can be adjusted to the required distance above the ground, and are arranged so that they will follow uneven contours. The material is collected in the curve of the prongs and dropped at intervals. The rake may be set to do this automatically, or the driver may do it by means of a lever.

Ram.—The monkey of a pile-driver. The tool arm of a shaper, or slotter. The plunger of an hydraulic lift, or a press. The hydraulic ram.

Ram Leather.—*See* **Hydraulic Leathers.**

Ramming.—Consolidating the sand around a foundry pattern. It is, in some of its details, a delicate operation, requiring good judgment, since the character of the ramming must vary in moulds of different kinds, and often in different parts of the same mould. The pegging rammer is used first to consolidate the sand in the vicinity of the pattern, followed by the flat rammer for the main body of sand. *See* **Moulders' Tools.** If the sand is rammed too loosely in a large mould, the pressure of metal will cause it to yield, and the casting will become lumpy. If rammed too hard, patches of sand will flake off, producing scabs. The more loose and open the sand, the lighter should be the ramming. Dried sand may be rammed practically as hard as possible, but not green sand. So, too, cores to be dried may be rammed harder than green sand cores. Sand in a top should be rammed harder than that in the bottom, and the more so the larger the area of the mould.

Ramps.—Appliances used for running derailed vehicles back up on to the rails. They are mild steel plates sloping up from the ground to the top of the rail, which they straddle over. The wheel of a vehicle, therefore, hauled or pushed up the slope alights on the rail. Ramps are single, that is they flank one side of the rail only, or they are double, flanking both sides. A set of the first comprises two left-hand ramps. A set of the second two double ramps.

Ramsbottom Rings.—Piston rings, of light section, designed by Mr Ramsbottom, bent, and sprung into grooves turned in piston bodies, and retained by their own elasticity only without the use of junk rings or plates. They are used in the smaller pistons. They work with little friction.

Ramsbottom Safety Valve.—A double safety valve invented by Mr Ramsbottom, and used almost chiefly on locomotives. The two valves are connected by a cross-bar which is made to resist the pressure of the valves by a spring anchored midway between the two. The valves have conical recesses in which the points of the cross-bar take their bearings. Such a valve cannot be tampered with, and the lift is direct. *See* **Safety Valve.**

Ramshorn Hook.—A double hook used on the heaviest cranes and travellers. For

any loads above about 10 tons, this type of hook is used in connection with a snatch block. A double sling chain is used with it, making the pull on the hook central through the axis around which it swivels.

Ramshorn Test.—One of the hot tests for iron and steel. The bar to be tested has a hole of elliptical shape punched through it near one end, the width of the hole being one-third that of the diameter of the bar. It is then drifted to one and a quarter times the diameter of the iron. A slit is cut down from the end into the hole, and the metal opened and turned back until the slit ends touch the bar.

Rape Seed Oil.—The seeds of the rough leaved winter rape, or coleseed (*Brassica napus*), yield the lubricating oil. The principal supplies come from the East Indies, and the Black Sea. The *Brassica Campestris* yields colza oil, used for illumination. Rape seed oil is a thick heavy oil. Its specific gravity at 60° Fahr. ranges, when refined, between ·916 and ·921. Its viscosity at 70° Fahr. is 246 to 225, Southern sperm oil being taken as the standard, or 100. Its flash point by the close test is 482° to 462° Fahr. The amount of free fatty acid present is from 2·8 to 4·67 per cent.

Rapping, or Loosening.—The act of loosening a foundry pattern in its mould, after it has been rammed, as preparatory to the lifting. The deeper the pattern, and the narrower and weaker the section of sand by which it is enclosed, the greater the need of rapping to lessen risk of fracture of the sand. Rapping is performed by inserting a pointed iron bar in a hole in the pattern, or in a metal plate or plates attached to it, and striking the bar laterally in all directions, so loosening the pattern sides. The effect is that the sand in contact with the pattern is pushed away slightly from contact, and when the pattern is lifted it does not drag against the sand, but has a slight clearance. In a deep pattern there is little or no clearance at the bottom, though there may be a considerable amount at the top. The mould will therefore be larger at the top than the pattern, and have more taper than that which has been imparted to the pattern. Moreover, in spite of every care there is nearly always risk in ordinary patterns, excepting those of small dimensions, and of shapes favourable to delivery, of some amount of fracture taking place, and then mending up has to be done.

These evils are avoided by the employment of stripping plates, and of moulding machines, in which such rapping as is adopted with hand-moulded patterns is unnecessary. The most that is generally done is a rapping on the face of the pattern plate during the time of withdrawal. But this is not like loosening laterally. It is just the same as the rapping done on the pattern face during the act of withdrawal, namely to assist in detaching the sand from the pattern. Some moulding machines have an automatic jarring apparatus which effects the same results.

Rapping Bar.—An iron bar pointed at one end, and used for loosening patterns in the sand. Sizes will range from $\frac{1}{4}$ in. to $1\frac{1}{2}$ in. in the smallest and largest diameters required. *See* **Rapping.**

Rapping Mallet.—A light wooden mallet used by moulders for striking blows on the top face, or the sides of a pattern during its withdrawal, to detach any particles of sand that may otherwise adhere to it.

Rapping Plates.—*See* **Lifting Plates.**

Rastrick Boiler.—A boiler which has not been made for many years, but examples of which were until recently retained in service in ironworks. It is an egg-ended boiler set with its axis vertically, and is therefore a dangerous type, due to its liability to seam rips, and many explosions have occurred in consequence. It is set in brick-work, and generally fired by the waste gases from the iron furnaces. Mainly it is externally-fired, but it has a centre tube extending to some distance up from the bottom, and four branch tubes leading therefrom to the enclosing brick-work. The brick casing is divided into four compartments by mid-feathers. Each compartment receives the waste heat of the various iron furnaces. The flame passes over the bottom and up over the breast of the boiler to the top of each compartment, and into the branch tubes. Thence it goes down the centre tube, and away by an underground flue to the chimney.

Ratchet, Ratchet Gearing.—Mechanism, the principle of which is its intermittent action.

It occurs in many forms, but the two essential members are the ratchet wheel, or rack, and the pawl, or dog, which drops into the tooth spaces, and so arrests the movement of the wheel or rack, or is itself arrested thereby. Ratchets run in one direction only, or in opposite directions, the forms of the teeth differing in each case. The first are radial on one face only, against which the pressure of the pawl is taken, the other face having a slope from root to point of adjacent teeth. The second have both faces symmetrical, being either radial or sloping.

Ratchet wheels fulfil the following functions:—They change a continuous motion into an intermittent one, as in the ratchets of hand cranes used in lowering heavy loads, or of a hand capstan, to hold the capstan in the intervals of pulling round, or the escapement of a watch. Reversing the action, a ratchet becomes a method of feeding—the pawl moving instead of arresting the ratchet. This is the case in the feeds of tool boxes of planers, shapers, and other machines — the *ratchet feed*, and in braces for drilling. An example of ratchet action, though not usually classed as such, is that of the pawl used for releasing some mechanism, as for example the drop of the ram of the pile driver, or of the ball used for breaking heavy scrap iron, the trip valve gear of some engines, as the Corliss, or the Cornish, or the trigger of a gun. Or reversed, the safety device for holding up a lift in case of the ropes breaking.

The pawls may either drop into the ratchet teeth by gravity, or be forced into engagement with springs. The latter is commonly adopted, and then the position of the pawl is unimportant, while a gravity pawl must have a position approaching the horizontal. Pawls which feed in both directions must be of spring type. The spring may be extra to the pawl, or be enclosed within it. Multiple ratchets are those which contain more than one pawl. They may be so designed to give equal pressures round a wheel, as in some forms with internal teeth. The common claw coupling may be regarded as essentially a multiple ratchet. Or they are used for the purpose of subdividing the pitch of the wheel teeth, as to obtain finer (applied in some grinding machines) and graduated feeds.

It is essential to the secure working of ratchet mechanism that the faces of the ratchet te shall not, by direct pressure between their fa and the face of the pawl, tend to throw the lat out of engagement. When practicable the thr should take place through the axis of the pa

Friction Ratchets.—In these, friction bloc the action of which is rendered intermittent means of suitable levers, take the place of pawl. The design is valuable as a *silent f* in wood-working machines.

Ratio.—Is the measure of the relation wh one quantity bears to another. The ratio 9 to 3 is 3, because $\frac{9}{3} = 3$; 9 is called the an cedent, and 3 the consequent. *See* **Prop tion**, and **Rule of Three.**

Two numbers are said to be in direct r when they increase or decrease together, the ratio remains constant.

Two numbers are in inverse ratio when decreases if the other increases, and *vice ver*

Raw-Hide Gears. — Gears built up layers of specially prepared ox-hide, the va of which lies in the capacity for smooth easy running at high speeds, no vibration noise being set up. Hence they are used lar in electrical drives of all kinds, and for l speed cranes. Being highly elastic there little risk of stripping of the teeth. They machine cut. They may engage with other r hide gears, but like mortice wheels, it is necessary to have one gear of the ela material, the other may be of any metal. T strength is about equal to that of cast-i gears.

The blanks are stored for several mon before being worked up, in order to thoroughly seasoned. There are various w of confining the laminæ of leather betw shrouding plates, the plates being of brass the smaller sizes, of iron in the larger. plates always extend to the point of the te Plain plates united with countersunk rivets commonly used, Fig. 199, A. Another wa to carry a boss on one plate right through body of the other plate, and rivet the two gether, B. The key groove is cut through boss. Large wheels are usually made wit cast-iron centre, C, the side plate being together with bolts, as shown.

Bevel gears of raw-hide are made; there i

formed resembling those in a common flat drill. The body steadies the tool, and enables a perfectly round hole to be made. Grooves down the outside conduct the lubricant to the edges. A *rose* reamer B (the original broach) has teeth cut on the corner, which is rounded; the objection to this type is that it cuts slowly, and is liable to clog. Very small reamers are made with flats, usually forming a hexagon in cross section. The most effective kind of tool is the fluted reamer, which has good cutting capacity, and ample clearance for the chips. C shows an ordinary hand type, with a cross section (enlarged at D) giving the form of the teeth and flutes. Instead of the flat relief, the Pratt & Whitney Co. use an eccentric relief, similar to that on backed-off milling cutters, which is stronger, and smoother in action than the flat. The teeth are usually spaced regularly around the diameter, but a few firms put the teeth at irregular intervals, the idea being that one tooth shall not fall into a recess left by the previous one, in case of chatters or irregularities developing, so that the hole will be smooth and round. Spiral teeth E are used, especially for long, and for tapered reamers, such as at F. The teeth are frequently notched out, F, leaving staggered sections, by which the chips are broken up into short pieces, that do not obstruct the action so much as when the cutting edges are continuous. A device intended to serve the purpose of drawing a reamer into its hole is that of forming a fine screw thread for a short distance up the end, thus pulling the reamer into its hole without the necessity of exercising end pressure.

Reamers used in machines have either tapered shanks, or if required for turret lathes, long shanks are provided, G, these being termed *chucking* reamers, because they operate on work chucked simply for boring, and facing. The larger tools are fitted on to separate shanks, to avoid using so much tool steel for a large number of shanks; these *shell* reamers, H and J (either straight or spiral), with fluted teeth, or rose teeth K, fit by a taper to their arbor L, and are driven by the key fitted against the shoulder, engaging in slots cut across the back of the reamer. Another class of chucking reamer is made with flutes resembling those in twist drills, and with a blunt nose, M. A hole is bored through, as shown by the dotted lines, when the tool is to be used with lubricant.

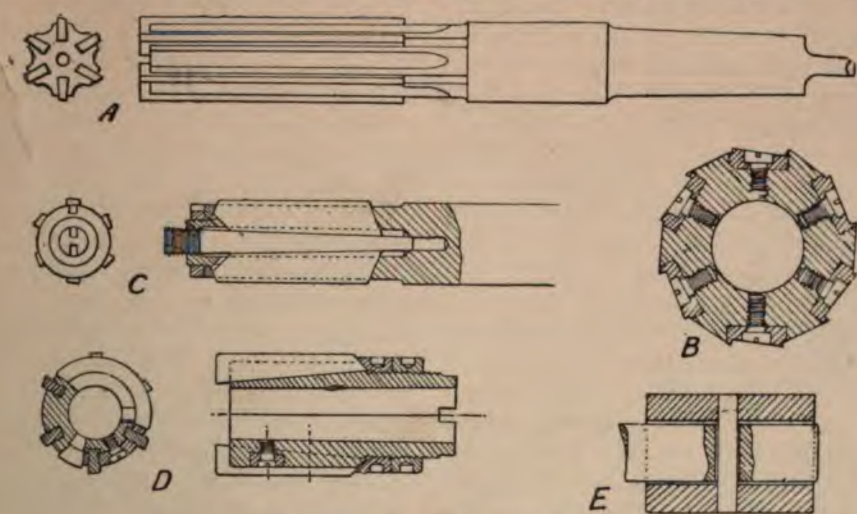


Fig. 201.—Adjustable Reamers.

All the solid reamers suffer from the defect that they will not retain their size, being reduced by grinding. There are consequently a number of types of adjustable or expanding reamers, by which standard sizes can be maintained. The action of inclined planes is utilised in many, such as the Rogers' type, Fig. 201, A,

point of recalescence more in lengths of is one cause of the casting of large ingots, is cooling, an inner and putting strain on inner portions.

in which molten metal until more metal is melted it. It may be necessary capacity of a furnace is in- quantity of metal required. Or order to obtain metal of greater more equable composition. Either plies to the cast iron melted in found- s, and the latter reason applies chiefly ixtures of iron melted in Bessemer r use in the converters. An example ver for a foundry cupola is illustrated **pola**; examples of those for Bessemer er **Metal Mixer**.

m receiver is also applied to a vessel formerly much used in compound n which the crankpins were located ngles to each other. The steam ex- rom the high-pressure cylinder into an ate vessel, whence the steam passed low-pressure cylinder. It had the t also of maintaining a fairly constant sure against the high-pressure piston, ducing the variation of temperature ylinder, but the same results are now in a more satisfactory and eco- way by the employment of triple engines, in which the intermediate steam chest, and pipes fulfil the f a receiver.

rocating Machine Tools.—A large rtant group which includes the plan- ng, and slotting machines in all their designs, fixed, and portable. They characterised by the alternation of a g with a cutting stroke, to which there exceptions, as that of the planers, with tool-boxes. It is usual in all but the achines to make the return non-cutting e place at a more rapid rate than the nging from twice, to six or eight times. sions of this class of machine range arge planing machines of common, pit, vertical, and side types to the small 6-in. shapers, slotters, key seaters, and portable slotting and shaping machines. In such a range there are many and varied problems to be attacked, and except in the fact of reciprocation there is little in common between the great groups into which these machines are divided. Many are highly specialised, designed for doing a single kind of task, others are made to combine several sets of operations. All the principal types will be found described under specific heads.

Rectangle.—A rectangle is a parallelogram with all its angles right angles. As regards the mensuration of the rectangle,

Area = length × breadth.
Length = area ÷ breadth.
Breadth = area ÷ length.

Area also equals the product of any two sides and the natural sine of their included angle.

To construct a rectangle, Fig. 203 (1), when the two sides, *a* and *b*, are given. Draw AB = *b*, and at A erect a perpendicular AD = *a*. With B as centre and AD as radius describe arc at C; with D as centre and AB as radius cut the arc at C, and join DC, BC.

To construct a rectangle when the diagonal AC and one side, *a*, are given (2). Bisect AC, and with the point as centre describe the circle. With A as centre and length of *a* as radius, cut the circle at B; and with C as centre and same radius cut the circle at D. Join the points as shown.

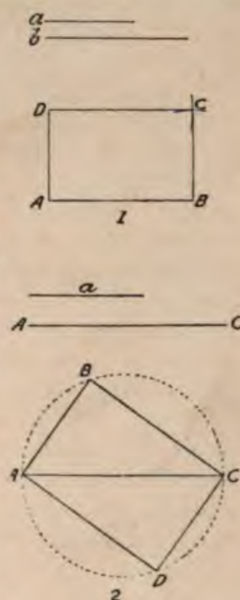


Fig. 203.—Rectangle.

Rectangular Boiler, or **Box Boiler**.—An obsolete design for marine service, which was displaced by the cylindrical or Scotch type when pressures began to exceed from 30 lb. to 35 lb. The shell was a plain rectangular box with convex edges. The flat sides were stayed very closely, as was necessary for their support

even against the moderate steam pressures. It was internally-fired, one boiler containing several furnaces; and of tubular design, the tubes returning from the combustion chamber to the smoke-box at the front. They were fitted with a rake of about one inch to the foot in order to raise them sufficiently above the furnace mouths at the front, to leave room there for the manholes. The furnace was well stayed to the shell.

The rectangular boiler was made in two distinct types; the *dry*, and the *wet bottom* respectively. In the first there was no water under the bottom of the furnace, in the second there was a water space between the bottom and the shell; the former was used chiefly in the merchant service, the latter in the navy. Much difference of opinion existed in regard to the relative advantages of each. Generally the smoke-box and uptake were fitted within the shell, but in many these were placed externally. One of the most terrible explosions on record occurred in a box boiler on the *Thunderer*.

Rectified Current.—Alternating current which is transformed down from a high potential to direct current of a strength required by consumers. Thus a two- or three-phase current of several thousand volts may be rectified to a few hundred volts at substations. For large powers the motor generator and the synchronous rotary converter are used. For small powers an electrolytic rectifier, or the mercury-arc rectifier are employed. The first-named consists of plates of an alloy containing aluminium, acting as a cathode, suspended in a salt capable of altering the condition of the polarising layer or film which is formed on the passage of an alternating current. The electrolyte may be contained in lead cells, forming the anode. The second comprises an exhausted glass vessel containing two anodes, one cathode, and one starting anode. The two anodes being connected across the terminals of the alternating current line become alternately positive and negative. The arc carrying the current passes alternately between each anode and the cathode. The latter is connected to the load circuit, the other pole being connected to a resistance coil across the alternating current circuit. The starting anode is for the excitation of the cathode. These rectifiers can be used for any voltage, and for any frequency from 25 to 140 ∽ per second.

Red Copper Ore, Cu_2O.—Cuprite, the red oxide of copper.

Red Deal.—One of the names given to a variety of fir wood (Coniferæ) of a reddish colour. It is imported from N. Europe. It is considered stronger and more durable than the white deal generally called spruce.

Red Hæmatite, Fe_2O_3.—An important oxide of iron which occurs abundantly in Cumberland, and on the shores of Lake Superior. According to the form in which it occurs it is variously called kidney, ochre, specular, micaceous, and massive hæmatite. Cumberland hæmatite contains over 90 per cent. of ferric oxide, about 5·6 per cent. silica, and less than 1 per cent. of each of the following impurities:—alumina, water, phosphoric acid, manganese oxide. *See* **Iron.**

Red Lead, or **Red Oxide.**—A compound of the monoxide and the dioxide of lead, having the composition $2PbO + PbO_2$. The substance is of much value in the machine shop, when mixed with oil, to form a very thin paste, which is smeared over parts that are being fitted mutually. The mixture being rubbed with the finger or a bit of waste on one face becomes transferred to another brought into contact with it, and the points or areas of contact indicate where metal has to be removed by filing or scraping. The faces of flanges in steam pipes, cylinder covers, &c., are smeared with a thin layer of red lead in oil, but the more accurate the metallic faces are, the less the thickness of red lead which is necessary or desirable. The seatings for manholes and other attachments to boilers are also made good with red lead, combined with tar twine, plaited.

Reducing Agent.—In the wider chemical sense a reducing agent is a substance capable, under suitable conditions, of removing oxygen, chlorine, or other element from a compound. Carbon, hydrogen, and aluminium are examples of reducing agents. In metallurgy, oxides of the metals are reduced by the action of carbon in some form. *See* **Reduction.**

Reducing Valve.—One, the function of which is to reduce a high and varying pressure of steam, air, or water to a lower constant

through the medium of a throttle-valve. are several designs, but they all embody ain elements; the valve itself, usually of ouble beat or equilibrium type, and the , or the diaphragm connected therewith, ich the reduced pressure is regulated by of a spiral spring, or a loaded lever r to that of a safety valve, the spring or being usually, but not invariably, below sing. The spring, or the position of the on the lever are made to regulate the of reduced pressure required.

thus:—A stop-valve may be temporarily introduced in place of the reducing valve to ascertain the valve opening required, with which at the maximum consumption of steam the required reduction is obtained. The size of reducing valve should not exceed four times the area opening thus arrived at. To calculate the size of reducing valve, the maximum consumption of steam must be determined first, then the required maximum opening of the valve may be calculated by assuming the steam will pass through the valve at a velocity, V, in feet per

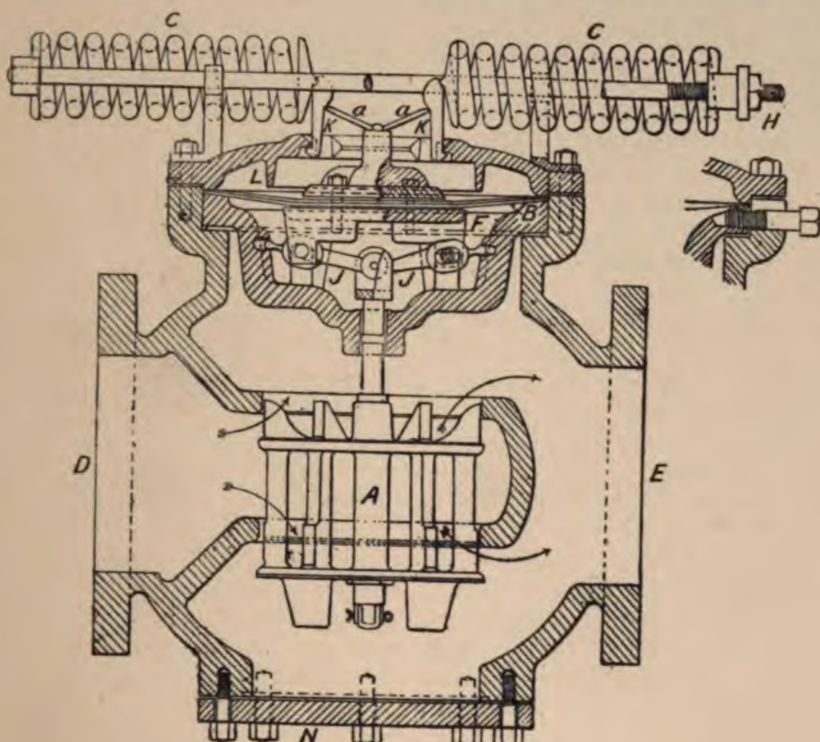


Fig. 204.—Reducing Valve.

e design seems a simple one, yet in fact subject to considerable variation in the of different manufacturers, and certain utions have to be observed. Reducing s should be smaller in diameter than that e steam supply, especially when the reon of pressure is large. A large valve so slightly that wire drawing results, consequent scoring of the seats. Messrs ffer & Budenberg recommend the detertion experimentally of the size required,

second = 10 R, where R is the reduction in pressure in lb. per square inch.

An ordinary reducing valve will not operate as a stop-valve. The latter should be fitted in the high-pressure steam pipe to shut off the steam when the consumption ceases. Designs are, however, made to include a hand stop-valve. A safety valve should also be fitted to carry away surplus steam in the event of reducing valves failing to operate.

We select for illustration a valve of equi-

librium and diaphragm type, which while including the main elements of that general type, is modified in several important details. As a result it automatically delivers steam which varies in volume with the demands made upon it, but still maintains a uniformly reduced pressure. It is Foster's patent, made by Messrs W. H. Bailey & Co., Ltd. The great advantage of this valve is the compensating spring movement. Other spring-controlled reducing valves will not open wider unless the pressure on the reduced side falls; the Foster valve will open to supply an increased demand, and at the same time maintain the required reduced pressure, without any alteration whatever in the spring adjustment. The illustration shows only one class of design, but there are a number of modified forms to suit all the varied conditions demanded by practice. In Fig. 204, A is the double-seated valve, which is lifted and closed by the action of the diaphragm valve B, in opposition to the power of the springs C, C. The steam or other fluid enters at D, passing out at E as indicated by the arrows. In its course it enters the diaphragm chamber F through the port, seen separately in the detail to the right, and so causes the diaphragm valve B to rise and close the valve A in opposition to the springs C, C. The function of these springs, which are adjusted by the nut H, is to produce equilibrium between the valve A and the delivery pressure on the diaphragm valve B, the tendency of the springs being to open the valve A against the pressure on the diaphragm B. Should the pressure on the delivery side increase, the pressure bearing on the diaphragm valve B overcomes the resistance of the springs, and tends to close the valve until the equilibrium is restored. And should the delivery pressure lessen, the springs overcome the pressure on the diaphragm, and open the valve until equilibrium is restored. The diaphragm, therefore, has very little movement, but this slight movement is multiplied on the valve A by the toggle levers J J. The action of the spring is communicated to, or resisted by the toggle links K, K, and *a*, *a*, by which endlong pressure is exercised against them. The delivery pressure is regulated by these springs by means of the nut K, an increase in tension increasing the delivery pressure. L is a safety ring to prevent accidental buckling or breaking of the diaphragm. M is a screw for closing entirely or partly the port G which makes communication between the valve and diaphragm chambers. The opening N at the bottom of the casing, closed with a flange, is used when an angle valve is required.

Reduction.—Is the process of abstracting an element from a compound, as oxygen from the oxide of a metal. Reduction is thus the reverse of oxidation. Metals are obtained from their ores by heating the latter in reducing furnaces in contact with substances having an affinity for oxygen. In the blast furnace, coal, coke, or charcoal—all forms of carbon—are used and the ore is deprived of its oxygen either by carbon or by carbon compounds. If carbon and oxygen unite, carbonic oxide, CO, is produced—$Fe_2O_3 + 3C = 2Fe + 3CO$; if carbonic oxide unites with the oxygen, carbon dioxide, CO_2, is formed—$Fe_2O_3 + 3CO = 2Fe + 3CO_2$. These waste gases then pass out of the top of the furnace and are led away for combustion, heating of kilns, &c., and the driving of gas engines.

Refined Iron.—*See* **Wrought Iron**.

Refrigerating Machinery.—The principles of refrigeration have been explained under the articles **Ammonia**, and **Ammonia Machinery for Refrigerating Purposes**. The present article will deal with some of the mechanical aspects of refrigeration in general.

As previously stated, the essential elements are three in number; the *refrigerator*, the *compressor*, and the *condenser*. The action of these is based on the principle that substances in passing from the liquid to the gaseous state (evaporation) absorb heat, and that in passing from the gaseous to the liquid condition (condensation) they give out heat. In a sense, therefore, a refrigerating plant is a form of heat engine, or heat pump. Put in the briefest terms, we can see that, following out the analogy of the steam agent, the efficiency of a refrigerating plant is wholly a question of *difference in temperature*, the difference between that of the refrigerator and the condenser, just as in the Carnot cycle of the heat engine. The question of the agent used, whether ammonia, or CO_2, or SO_3, is identical with that of the agent used in the heat engine, whether steam,

gas, or air. Also it is not a question of obtaining theoretical results, but of what can be done under imperfect practical conditions. The importance of economical working is apparent when the fact is borne in mind that a ton of coal is consumed in making from 8 to 10 tons of ice. In refrigeration which is effected by the evaporation of a liquid it is essential that the liquid should have a very low boiling point, otherwise it will not take up the large amount of heat necessary. Carbonic acid has the low boiling point of −125° Fahr. The latent heat of a substance, or that which is absorbed or given out without raising the temperature during the transformation of a solid into a liquid, or a liquid into a solid, respectively, is of value. The latent heat of ice is 142·5 heat units. The particular use made of the change from the liquid to the gaseous condition is the abstraction of heat from, and the refrigeration of the substance surrounding the agent. This is the function of the *refrigerator*. The compressor and the condenser are simply of secondary interest, the functions of which are to restore the spent gas to its original liquid condition. This cycle goes on constantly with little waste of the agent used. The pump and condenser are not strictly essential, and might in fact be dispensed with if the ammonia or carbonic anhydride cost nothing.

The Agents of Refrigeration.—These are ammonia, carbonic acid, or strictly carbonic anhydride, and sulphurous acid. The two first agents are by far the most commonly used, being more efficient than the third. Much difference of opinion exists as to the relative value of ammonia, and carbonic anhydride. The early development of both was due to Dr C. von Linde. The objection to the first is the danger due to the poisonous character of the gas in the event of escape. The Board of Trade do not allow machines using ammonia in the main engine-rooms of vessels, while they permit machines using CO_2 in the engine-room. But the fact remains that ammonia plants are used far more extensively than the CO_2.

The Evaporator.—Essentially this comprises a rectangular vessel containing brine (hence termed the *brine system*), and traversed by a continuous series of coils of pipe through which the ammonia, or the carbonic anhydride travels. The evaporation of the ammonia in its passage through the coils is caused by the great difference in the temperature of it and the brine. The salt is added in order to keep the solution from freezing. The amount of salt added to the water is regulated by the temperature at which the brine is required for use. The higher the temperature, the less salt required; but the highest proportion possible is 25 per cent., because that is as much as water will hold in solution at 0° Fahr. Brine is used instead of pure water because the temperature of its freezing point is lower than that of water. Its boiling point is also higher. But as already stated, a solution too strong will lower the specific heat, and cause risk of choking the pipes with deposit. The tables show the lowering of the freezing point for solutions of different strengths.

SOLUTION OF CHLORIDE OF SODIUM.

Percentage by Weight.	Freezing Point. Fahr.	Percentage by Weight.	Freezing Point. Fahr.
1	30·5°	15	12·2°
5	25·2°	20	6·1°
10	18·7°	25	0·5°

SOLUTION OF CHLORIDE OF CALCIUM.

Percentage by Weight.	Freezing Point. Fahr.	Percentage by Weight.	Freezing Point. Fahr.
1	31·0°	15	15·0°
5	27·5°	20	5·0°
10	22·0°		

Brine is made indifferently from chloride of sodium, or chloride of calcium. An advantage of the latter is that the pipes do not become incrusted so badly as when salt is used.

The effect of passing the ammonia, or the CO_2 through the coil surrounded with brine is that the brine takes up heat from the liquids. Since ammonia boils at −29° Fahr. the brine is very hot by comparison, and the ammonia extracts heat therefrom as long as it is in contact with the brine, or until the latter has been reduced to a temperature which corresponds with the pressure under which the ammonia becomes gasified. The action is identical with that which goes on in a water-tube boiler, only that brine takes the place of fire, and ammonia or carbonic anhydride occupies the tubes instead of water. In the one case the vapour of water is produced, in the other the vapour of NH_4, or of CO_2.

Though the temperature of the brine is reduced it does not freeze, and is now available for circulation through coils of pipe carried round the chambers which have to be cooled. The circulation is the function of the *brine pump*, and the system is termed the *brine system*, as distinguished from the *direct expansion system*. In the latter the air in the chamber serves for heating the ammonia, the coils being carried round the chamber; and the brine tank, and the brine pump are dispensed with. Brine when used takes up heat from the chambers, cooling them, and is returned to the brine tank, where it renders up heat to the ammonia, or the CO_2.

Compressor Pump.—The function of this is to draw off the gas from the refrigerator, and compress and deliver it to the condenser. As these pumps work under great pressures they are of the ram type, and made of exceptional strength from bronze alloy, or in some cases bored from solid steel. The suction and delivery valves are of steel, or bronze alloy, on bronze seatings. The ramrod gland is packed with hydraulic leathers, and an oil chamber provides lubrication. The pump is belt driven. It is made either single, or double-acting.

The Condenser.—In this the gas is received from the pump, and circulated through a coil of pipe surrounded with cooling water. There are two systems used, the submerged, and the surface evaporative, or open air type. The first is submerged in a tank of water, the second is in the open air, and the water is made to trickle down over the pipes by gravity. The first is preferable in situations where there is an ample supply of water, the second is suitable for the opposite condition. The first has the advantage that the warm gas enters the pipes at the top, and the cold water enters the tank from the bottom, and thus the liquefied gas leaves the condenser where the coldest water is. In the surface condenser the water trickles down over the pipes, and the liquefied gas and water warmed by contact with the pipes part company at the bottom, which is not so efficient an arrangement as the former.

Ice Making.—This is not the same thing as refrigeration for cold storage, though the principle adopted is identical. In many cases the two are combined in one plant. Ice is manufactured from the pure drinking waters of cities, or from artesian wells, and is therefore more pure than ice taken from natural sources. It is also made in the locality where it is consumed, and therefore the cost of transport and extensive storage is set off against the expense of the plant. Manufactured ice will last longer than natural ice.

The evaporating coils of pipes, surrounded with lime, are enclosed in tanks of metal or wood, and the ice moulds are submerged in this, and the water so frozen. Moulds are made in various dimensions, and the time occupied in freezing depends on the thickness, and the temperature of the brine, and may range from twenty to fifty hours. An overhead crane, or tackle, is fitted for lifting the moulds out of the tanks. The machinery required is similar to that for refrigeration, and includes compressor pump, condenser, and motive power, as engine and boiler, with the necessary piping.

Insulation.—The insulation of chilling rooms is a very important detail. If it could be made perfect there would be no loss to make up to take the place of heat absorbed from without. Hence there are a good many various arrangements of floors, walls, and ceilings, to maintain a low temperature as long as possible. Because of this also refrigerating plants are not so efficient in tropical countries as in cold ones. The methods of insulation adopted are walls of boards, three or four in number, tongued and grooved, with spaces between each wall filled with some insulating substance. The best insulators are grey blotting-paper, air, cotton, granulated cork, pitch, charcoal powder, sawdust. Windows are also made with two or three separated sashes, leaving air spaces between.

It is almost impossible to give data of a general character relating to installations of refrigerating plant. Its design is the work of experts who have to take a large mass of data into consideration before advising on the subject. The particular applications of refrigeration require modifications in detail. It finds application in cold storage of many kinds of produce on land and on board ship, for carcases of

animals, fish, fruit, vegetables, dairy produce, as well as ice-making, and in small and large installations, besides which the practice of different firms is varied in regard to both general designs and details, and in the utilisation of different systems.

Refuse Destructor.—*See* **Destructor.**

Regenerative Furnaces.—Gas-fired furnaces in which heat that would otherwise be lost is stored in a chequer-work of brick, to be rendered up to gas and air for utilisation in the furnaces. These are the outcome of the early efforts of Sir William Siemens to design a regenerative steam engine. Subsequently, in concert with his brother Frederick, who took out a patent in 1856; and with the substitution of gaseous for solid fuel in 1861, many of these furnaces were made, and were in successful operation in 1862. Originally the intention was to utilise them for glass melting for which work Messrs Chance of Birmingham had several built. But steel melting had been provided for in the patent of 1861. Some years elapsed before this application was successful. Messrs Pierre & Emile Martin of Sireuil, Charente, achieved the first real success by producing open-hearth steel working under a license from Messrs Siemens. Siemens' first patent for the manufacture of open-hearth steel was taken out in 1867. An example of an open-hearth furnace with regenerators is given in Vol. VI., page 239.

In chequer-work, the bricks are arranged so that the air spaces alternate with the bricks. The most important point to observe is to have the regenerative surfaces of ample area. If this is done, it is a matter of less importance whether the gas regenerators are larger than the air regenerators, which is often the case. The waste gases in their passage are drawn downwards by the chimney draught, coming in at the top, and passing away at the bottom of the regenerators. Hence depth is essential, deep chambers being more efficient than shallow ones, even though of the same area. The temperature of the escaping gases may be reduced as low as 300° Fahr., while the upper part of the regenerators is nearly as hot as the furnace. The producer gas and air in their passage to the furnace are being simultaneously heated in another pair of regenerators, previously heated by the waste gases, and finally mingle on the hearth of the furnace. And this goes on with reversals of the valves occurring about every twenty minutes. The relative supplies of air and gas are under control, so that reducing, neutral, or oxidising flames can be obtained. There is practically no limit to the temperature obtainable, the difficulty is to preserve the refractory materials used from too rapid destruction. The amount of regenerator surface required to absorb the heat generated by 1 lb. of coal is usually reckoned as from 6 ft. to 8 ft.

Register Numbers, or **Letters.**—Letters cast or stamped on pieces of work for the purpose of identification of the castings or forgings when ordered subsequently for repairs and breakdowns. They also facilitate the work of fitting, assembling, or erecting. They may or may not be associated with an interchangeable system. With large pieces, strict interchangeability is scarcely practicable since some little easing or adjustment may be required. But the smaller pieces should go into their places without any adjustment or correction. Whether they do or not depends on the system of manufacture in a shop.

Register letters are cast on large pieces, and those of medium size, and are stamped on small parts with letter stamps. In die-forged articles they can often be stamped in the dies. In cast work the letters may be fitted as in **Name Plates.** But it is a common practice to sink the register letters slightly below the surface in a neat and shallow recess, the object being twofold. It protects the letters from damage, but the principal reason often is to allow metal for machining without obliterating the letters.

The system of registration varies in different shops. The essential is to have something which can be readily identified. Each part in a piece of machinery must have its own separate number, except in those instances in which several parts are absolutely identical in all respects. But each part of the machine must also have one sign common to that particular machine, or class of machine. This is usually a letter, or letters of the alphabet; so that the register letter and number in combination enable any piece to be identified at any period. The

different parts are usually numbered correspondingly on the drawings, and time and materials may be charged by the numbers, singly, or in sets. The names of the different parts need never be stated, the register numbers being sufficient for identification.

Regulator.—The valve which admits and controls the supply of steam from a locomotive boiler to the cylinders. *See* **Steam Regulator.**

Regulus.—A term which signifies definite stages in the reduction of the metals copper, and antimony. It is an impure product, also termed *matt.*

Reheating.—Relates to various arrangements and devices by which piles, blooms, and billets of wrought iron, and ingots and slabs of steel are raised to a uniformly high temperature to permit of reduction in the hammers, and rolls of the forges and mills to the dimensions and shapes in which they are used.

Reheating Furnaces.—Furnaces in which steel ingots, slabs, or blooms, or iron piles and blooms are reheated thoroughly through, preparatory to reduction under the hammer, or press, or in the rolls. They are of reverberatory type, but differ in methods of firing. The older furnaces were coal-fired, using natural draught, and much difficulty was experienced in proper regulation of the heat over the hearth, while the waste of fuel and by oxidation was excessive. The first improvement in these was the introduction of forced draught by steam jets beneath the grate in a closed ashpit. By this means slack can be used instead of solid coal, with reduction in cost, and by regulating the draught the thickness of the fire is under control. Air is also supplied above the fuel. The quantity as well as the cost of fuel is reduced, and the oxidation is less.

In modern slack-fired furnaces a much larger volume of heat is produced than can be utilised on the hearth. This is employed for raising steam in the mill boilers, and in this way the amount of fuel actually used in reheating may be reduced to one-half that required when the waste heat is not utilised in steam raising, and to little over one-third of that in the old solid-fired furnaces.

Gas-Fired Furnaces.—These, fired with producer gas, and having regenerators are now largely used. The regenerators are built underneath the furnace. The difference between a steel making furnace of this type and a reheating furnace consists chiefly in the larger dimensions of the grate of the latter, because the temperature is not so high, and the grate is not sunk below the level of the charging doors. The great advantages are that the inferior fuels used in making the producer gas yield combustible gases of a higher calorific intensity than they would do if burnt in their natural state, and that the temperatures required can be regulated exactly by the passage of the air and gas through the regenerators.

The Boëtius, and the Bicheroux reheating furnaces have been adopted extensively on the Continent, but they have fallen generally into disuse. They aimed at economy in construction by making the gas producer a part of the furnace, and avoiding the use of regenerators. The gas passed directly to the hearth, and the air, heated in flues in the furnace walls, met the gas at the fire-bridge. Recent furnaces which do not use regenerators are the Pietzka, and the Hollis.

Reheating is avoided in the case of large ingots by checking the radiation of the heat of the outer portions, until the heat of the inner body is transmitted through the outer. The idea was due to Mr Gjers, and is practised extensively. *See* **Soaking Pit.**

Reins.—The handles of withy, or iron, of smiths' tools.

Relief—Angle of.—*See* **Angles of Cutting Tools.**

Relief Frame. — *See* **Balanced Slide Valve.**

Relief Valve, or **Escape Valve.**—A small lift valve held down by a spring of definite strength which yields when a certain pressure is reached. Such valves are fitted to large engine cylinders, to allow the escape of water from priming or condensation. They are attached to both ends of the cylinders. Relief valves are also fitted to some pumps to permit of escape of fluid when the pressure exceeds a certain amount.

Relieving Lathe. — *See* **Backing - off Lathe.**

Repose—Angle of.—The angle of friction. *See* **Coefficient of Friction.**

Repulsion Motor.—One in which the stationary circuit is used as a primary circuit energised by the main circuit, and in which the armature is closed upon itself as secondary, by short-circuiting the brushes. The hysteresis loss of the repulsion motor is lower than that of a similar motor designed as a compensated series motor.

Residual Magnetism.—It is found that immediately after a strong magnetic force has been applied to iron, the metal possesses a greater degree of magnetic strength than it can permanently retain. After a time this excess of strength is lost, and the term "residual magnetism" is applied to what permanently remains.

Resin.—Also called rosin. It is a compound of carbon, oxygen, and hydrogen, occurring naturally as an exudation from coniferous and other trees, and hardening on exposure to air. It is a translucent substance of vitreous fracture, scarcely odorous, yellow or brown in colour, and possessing a slight taste of turpentine. The hard resins are used for varnishes, the softer oleo-resins and semi-fluid balsams for pharmaceutical and scientific purposes. Amber, African copal, and kauri gum are fossilised resins. Resin is used as a flux in soldering. It is also used as a belt dressing when mixed with tallow.

Resistance Box.—A set of resistance coils mounted in a frame or case; also called a rheostat. German silver is the material usually employed for the coils, and they are simple spirals, or are wound on bobbins. The strength of a current is thus varied by moving a switch, which connects up or cuts out the coils in succession; a separate **Controller** may be used for this purpose. The ordinary resistance frame is of cast iron with slate slabs bolted at opposite sides, and having bolts which receive the ends of the coils. The switch is fastened to a slate slab below, and the contact studs connect to the coils above.

Resolution of Forces.—*See* **Force.**

Rest.—*See* **Slide Rest, Tool Boxes.**

Retaining Walls.—A retaining wall is a brick, stone, or concrete wall intended to sustain the pressure of earth, sand, or water. But the last-named is generally called a dam. Assuming that a wall for any of these purposes is safe from sliding or settling into the soil the danger to be encountered is that of its being overturned. In calculating the forces acting on a retaining wall it is usual to consider only one foot length of the wall; the number of cubic feet in the wall is then the number of square feet in the cross section. In the case of a dam the pressure of the water against it will vary at different depths, being least near the surface and greatest at the foot. The average pressure will be half the depth multiplied by 62·5 lb., the weight of a cubic foot of water; the total pressure will then be the area of wetted surface × average pressure.

The pressure of the water tends to overturn the wall on its edge. This is resisted by the

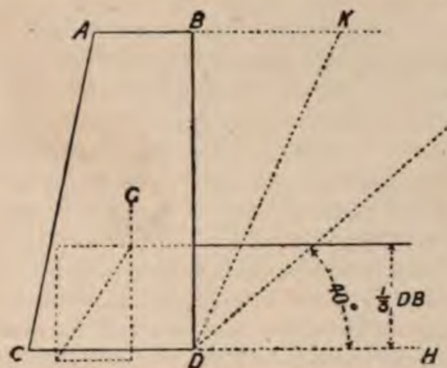


Fig. 205.—Retaining Wall.

weight of the wall acting at the centre of gravity. If the moment of P exceeds that of W the wall is unstable. A simple method of testing the stability of retaining walls for water by the application of the resolution of forces is described under **Dam.**

The case of a retaining wall for earth, &c., differs from that of a wall supporting the pressure of water. The pressure sustained by such walls depends on what is known as the "natural slope" of the material supported. This is the slope which a bank of sand, earth, clay, gravel, &c., would eventually acquire and permanently retain if left exposed to the weather. The angle varies for different materials; for gravel it is 35°-48°, for sand 21°-37°, earth 29°-40°, damp

clay 45°, and so on. The angle of natural slope is first set off, Fig. 205, FDH. As regards pressure against the wall, the wedge of earth FDH may clearly be neglected, but the wedge FDB tends to slide down, and it is this pressure which the wall has to sustain. It is found moreover that the greatest pressure is received from the wedge BDK, which is $\frac{1}{2}$ BDF. For if the wall were overturned, DK would be the line of fracture in the earth and consequently its temporary but not final slope. DK is therefore called the line of rupture.

The calculation of the pressure of earth can at most be only approximate. Rain, frost, drought, affect the weight, and, of course, the angle of slope, so that a wide margin of safety is allowed. Of many formulæ the following is largely used:—

$$P = \frac{\text{weight of triangular prism of earth BDK} \times \text{BK}}{\text{BD}}.$$

As in the case of dams, this force is considered to be applied at a point one-third up from D. For the resistance of the wall a vertical line is dropped from the centre of gravity to cut the horizontal line of force, and from this point the thrust of the earth and the weight of the wall are set off to scale, the parallelogram completed and the resultant drawn. The point at which the resultant cuts the base is all-important. In dams it is advisable that it should cut within the middle third of the base. In walls for earth a point from the edge one-fourth or even one-fifth is permissible, but much depends on the masonry, the foundation, and whether or not the material will bear any tension.

Retort Charger.—A form of mechanical stoker, employed for charging gas retorts. Both manual and power driven machines are used, the former for small works. The charger runs either upon rails on the floor, or on suspended tracks, and comprises a framework carrying a hopper with a supply of coal, which is fed on to the charger proper, consisting of a long carriage made with a couple of semicircular scoops; these receive the coal, and are pushed into a retort, after which they are caused to fall apart and so drop and distribute the coal evenly in the retort. Withdrawal is then effected, the machine being moved along to another retort. Elevating mechanism is provided for raising or lowering the scoops to suit the heights of the different tiers of retorts. Power driving systems include ropes, compressed air, and hydraulic. In the first system the ropes run the length of the retort house, and transmit power to shafts on the chargers, from which belt pulleys operate the movements of travelling, elevating, and charging. In the compressed air machines the power is conveyed through flexible hose to a motor on the charger, which performs the functions of travelling, and of elevating, and an air cylinder does the charging, through the medium of a rack and pinion, and chains. The hydraulic method also includes a cylinder for performing the charging operation. Drawing machines are of simpler construction than chargers; they are provided with a rake for drawing the coke from the retort.

Return-Tube Boiler.—A boiler in which the products of combustion return from the rear end of the furnace through tubes which traverse the water space above the furnace, and thence pass into the smoke-box and chimney. For an example *see* **Scotch Boiler**.

Reverberatory Furnace.—Also called *air furnace*, because natural draught only is used. It is a furnace in which the fire-grate is separated from the *hearth*, or *bed*, so that the ore or metal on the hearth is not brought into contact with the fuel. The hearth is separated from the fire-grate by a low bridge, over which the flames pass up to the roof, and the latter is arched downwards towards the farther end where the chimney is situated. The arch and the sides being built of brick-work, retain heat, which with the hot gases is deflected on the hearth. Particular forms and proportions are varied to suit different metallurgical processes, but the general design is on these broad lines.

Reverberatory furnaces are used for reducing ores of several kinds, for making steel, and for melting metals and alloys which would become injured by contact with fuel. It is often employed alternatively to crucibles, as when large quantities of brass, gun-metal, and steel are wanted for heavy castings. When cast iron is required very pure it is melted thus. Large masses of scrap, also, which cannot be broken readily are often melted on the hearth of one of these furnaces. Aluminium is thus melted for

foundry use. The boiler-maker and plater heat plates, angles, channels, and all sectional forms for bending in this furnace. Coal, coke, and producer gas are variously used for fuel.

Reversing, Reversing Devices.—These occupy a place of increasing importance in modern mechanism, as greater demands are being made upon self-acting movements, or acceleration of reversals. The necessity applies to nearly all machines and machine tools, the movements of which cannot go on for ever in one direction. Either the tool or the work must be brought back to the point from which it started, at definite and regular intervals. This is in many cases accomplished by the intervention of the attendant, but in a greater number of instances it is effected by devices embodied in the actual movements of the machine.

Hand-operated Reversals.—A familiar example is afforded by the slide rest of a lathe which is racked back by hand as often as a fresh sliding traverse has to be taken. The clasp nut is thrown out from connection with the lead screw when screw cutting is being done, and after racking back, is thrown in again. So the cross traverse of the slide rest is run back by hand between each cut. As in the lathe, so in many other machines, rapidity of reverse is effected by means of a rack in preference to using the slower screw. Sometimes a quick pitch screw is fitted for reversing. A frequent device for reversing is a nest of bevel gears enclosing a friction or claw clutch, operated by a hand lever, whence movement is communicated to the screw used for traverse and reverse. The device of reversal by belt shifting from a countershaft is familiar, open and crossed belts driving in opposite directions, or reversal by gears from a single belt, and this is common in many machine drives.

Large numbers of reversals, though effected by power, require the intervention of the attendant to throw different sets of toothed gears into engagement, or to operate link reversing motions, or to admit steam to reversing cylinders, or to throw over belts. In many cases this must be so, as in the lifting and lowering of cranes, of slewing in opposite directions; in reversing rolling mills, or in reversing marine engines, none of which operations can be timed to take place at definite periods, but must be effected to correspond with operations and movements which are always of a variable character. In all these cases the problems to be solved are rapidity, precision, and ease of movement.

Self-acting Reversals.—These include an immense number of designs, having for their object the semi- or complete automatic action of the machines to which they are fitted.

Generally some form of trip is designed, actuated by dogs on a rod, which are set in such positions on the rod that they cannot fail to be struck by the movement of the carriage which carries the tool or the work. As the dogs are clamped to the rod the movement which they receive is communicated to the rod. This is then transmitted directly to whatever type of reversing mechanism is embodied in the machine; whether a clutch and bevel gears, worm gears, with a drop worm, open and crossed belts driving a screw direct, or driving a train of spur gears, or an open belt driving reversing gears, or to turn a turret. The dogs need not be on a straight rod, but as in some turret lathes may be adjusted on the edge of a rotating disc. Or cam movements are used for the traverse and reverse of a tool, or work slide.

Generally the rate of reverse is more rapid than that of cutting, the limit to this rate being either the amount of shock the mechanism will stand, or the amount of power required to effect reversal. The highest speeds of reversal occur in the pneumatic tools—the chisels, and caulkers. In a few machines cutting is made to take place on both strokes, and then the rates of reversal and cutting are alike. So too in reversing rolling mill engines, no difference is made. In nut tapping, and much screwing the reversal is quicker than the cutting. But in a great deal of screwing the dies are opened, and thrown off clear of the work without reversal.

The Reversal of Reciprocating Parts.—This is better understood than formerly. In brief, the principle is the cushioning of the action just at its termination; or the utilisation of the momentum of the parts to lessen the shock of reversal. The most familiar example of the first is in the steam engine, in which the opening to steam by the lead of the valve just before the termination of the piston stroke,

softly cushions the movement of the piston immediately prior to its reversal. The other is that effected by mechanisms, some modern examples of which are illustrated under **Planing Machines**.

The influence of momentum and inertia of moving parts, due to their weight, and velocity, to which must be added the driving pressure exercised on them, whether steam, or belt power, increases as the square of the velocity. Hence the problem involved is to keep down the weights and speeds of the parts as much as possible. Speed can be increased if weight is lessened, and *vice versa*. But high speeds require high pressures. It is possible to so regulate the piston speed, the weight of the reciprocating parts, the steam pressure on the piston, the point of cut-off, and the amount of lead as to obtain smooth running at the highest speeds. It is understood that cranks must be properly counterbalanced, and the pistons also in compound engines. The locomotive engine, the triple and quadruple expansion marine engines, the reversing rolling mill engines, and the high-speed engines for electric lighting afford the best examples of reversing.

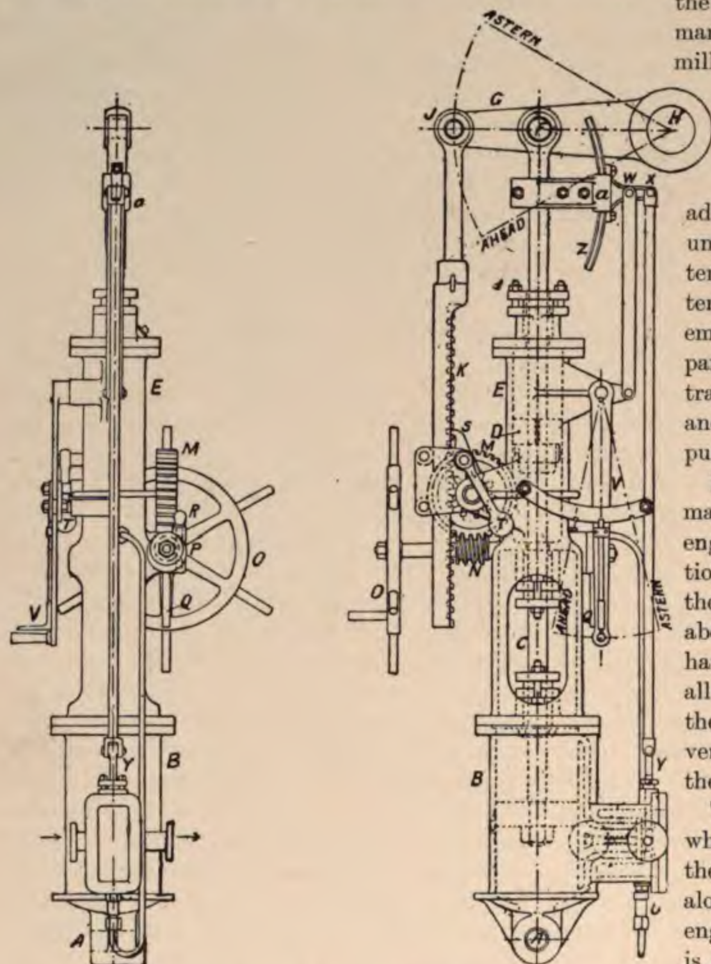


Fig. 206.—Reversing Engine.

In planing machines, in addition to the devices shown under that head, there is an interesting and successful design termed the *Mitchell drive*, which embodies heavy rotating reversing parts, and which is fitted as an extraneous addition to any machine, and utilises its momentum for the purpose of easy reversal.

Reversing Engines.—In the marine service these are small engines used for reversing the rotation of the main engine. Only in the smallest engines, or those under about 100 HP., can reversal by hand be effected. It is usual in all others to fit an engine to act on the weigh-shaft, causing it to reverse the slot links which actuate the slide-valves.

The simplest gear is that in which a steam cylinder is fitted to the ordinary hand gear. But this alone is not quite suitable for large engines because the steam cylinder is apt to overrun and damage the gear. Hence it is better to control the steam piston by a brake piston in a second cylinder. This is the principle of Brown's reversing gear. In this gear the valve motion of the steam cylinder is actuated by a hand lever, and the amount of movement of this lever controls a similar movement of the link motion. Side rods on each side of the piston rod are connected directly to levers on the weigh-shaft. The engine is

attached directly to the A frames of the main engines.

Fig. 206 illustrates Brown's patent combined steam and hydraulic reversing engine. It is fitted with independent hand gear, and automatic cut-off gear. The engine is attached to the bedplate or column of the main engine by the oscillating joint A, formed on the end of the steam cylinder B. The piston rod C has cottered to it a block piston D, working in the hydraulic cylinder E, the fluid being allowed to pass from one end to the other of the cylinder E by means of a small hole bored in the piston D. The rod C passes through stuffing boxes on the steam and hydraulic cylinders, terminating in a joint F pivoted to the weigh-shaft lever G, H being the shaft. The other end of the lever is jointed at J to the rod and rack K gearing with its pinion, both being shrouded to the pitch line. Upon the pinion shaft is keyed a worm wheel M, which is actuated by the bronze worm N revolved by the hand-wheel O. The worm and hand-wheel shaft are thrown out of gear with the worm wheel by the eccentric P, which is turned by the handle Q, and held in position by the check pin R. When the hand-wheel and worm are disengaged, the rack and worm wheel are free to revolve when the engine makes a stroke either way. This hand gear, therefore, forms no integral part of the starting engine, and is unaffected by any derangement of either hydraulic or steam cylinder, or the steam valve.

A locking arrangement on the hand gear is provided, so that the main valve gear can be linked up in any position of the ahead stroke. This consists of a pawl, S, which is made to engage the teeth of the rack, and the engine is held up against the pawl by reason of the slide-valve being left slightly open to steam. The pawl is provided with a balance weight T, so that on the engine being reversed for the astern position, the weight immediately pulls the pawl out of gear.

The hydraulic cylinder is kept charged by means of the condensed steam in the bottom of the valve casing, being driven by the steam through the non-return valve U, and led by a small copper pipe as shown into the lower end of the cylinder.

The engine is handled by a simple reversing lever V, which is connected by two links to the fulcrum of a lever at W. This lever has its end extended to X, which is connected directly by a link to the valve spindle Y. A curved link Z is securely attached to the lever W, X, and on this there slides a block *a*, which is carried from the piston rod.

The action of this valve gear is as follows:—When the lever V is pulled into the ahead position, the lever W, X, which is attached to the curved link Z sliding in the block *a*, is depressed. The valve spindle is also moved down, opening the top end of the cylinder to steam. The piston rod now begins to move down and carries with it the guide block *a*, which forces the end of the curved link to move into the centre line of the block, thus moving the point X of the lever W, X in an upward direction, the fulcrum at W by means of the reversing handle V being held stationary. In this way the valve spindle Y is brought back into its original position, thus bringing the engine to rest. The same operation is performed for the astern, or any intermediate position.

It will be seen that there are only three joints in the valve gear, apart from the sliding block *a*, and there is no revolving motion of the valve rod, as in the old cut-off with the spiral and nut, which caused considerable friction and wear and tear.

A reversing engine of which large numbers have been made actuates the reversal of the weigh-shaft through a worm and wheel. The worm is on the crankshaft of the reversing engine, and the wheel has its bearings in a convenient position in the framing of the main engine. A stud on the disc of the worm wheel receives one end of a connecting rod, the other end of which is attached to a lever on the weigh-shaft. The worm wheel, being thus revolved by the engine, oscillates the weigh-shaft, and reverses the links. A reversing engine must be prompt in action, so that the main engines shall be capable of reversal and moving full speed astern within thirty seconds.

A detailed drawing of a reversing engine of the last named type is illustrated, Fig. 207. It is by Messrs William Doxford & Sons, Ltd., who fit this type to all engines up to 2,000 HP.

The cylinder casting A is in one with its valve casing B, and with the steam chest C, which contains the reversing valve D. This valve controls the steam supply to the piston valve E.

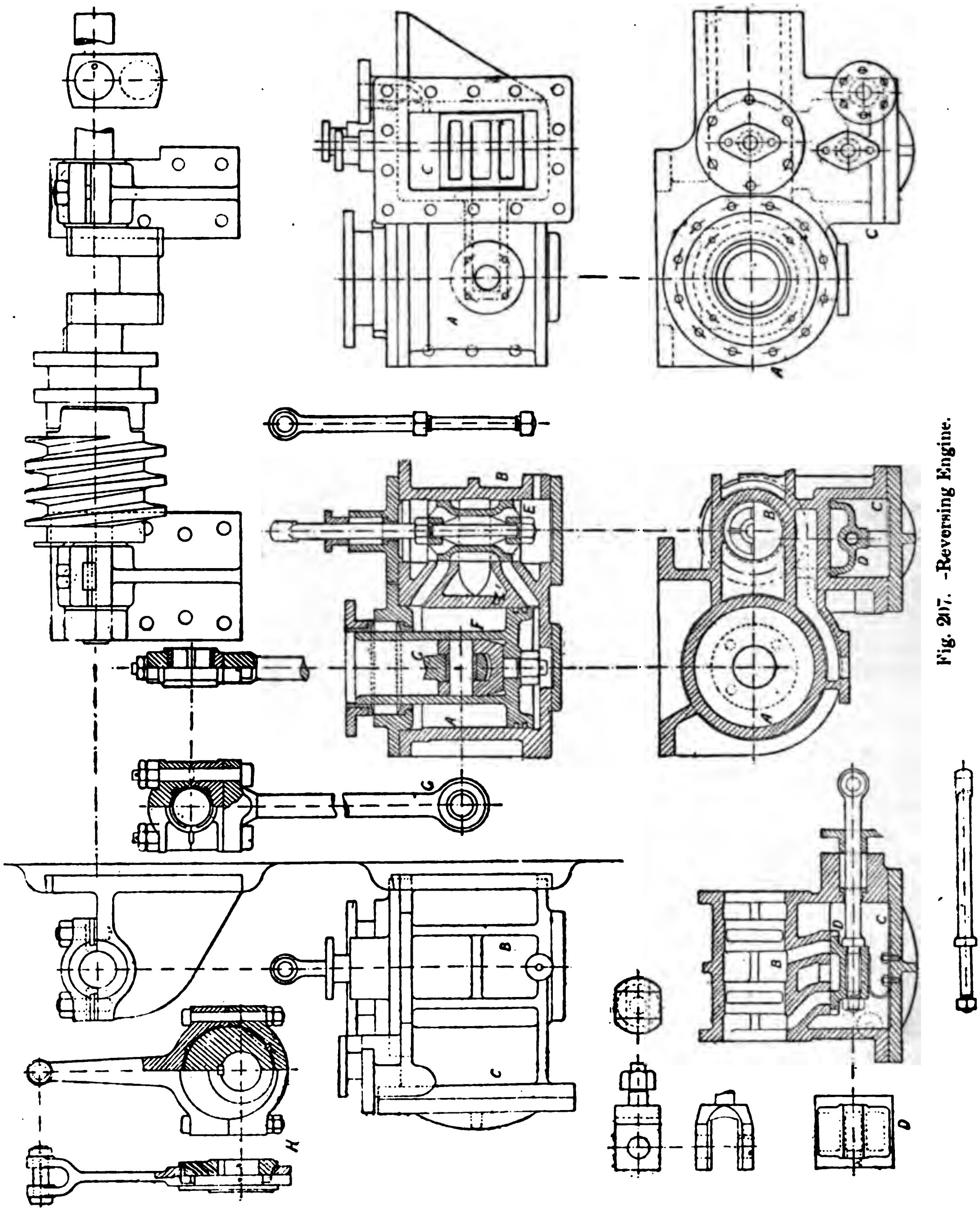


Fig. 207. -Reversing Engine.

The piston F of the reversing cylinder is a combination of the flat and trunk forms. The trunk is rendered steam tight by a stuffing box, neck ring, and cover. The connecting

rod G is fitted in gas engine style. The eccentric rod H for the piston valve is shown separately; the travel of the valve is $1\frac{1}{2}$ in. The crank and its bearings, the worm, and other details are all apparent.

Reversing Rolling Mill.—Though many continuous mills have been electrically driven, it is only within about a twelvemonth that electricity has been successfully applied to reversing mills on the Continent. At the present time there are four mills of this kind in operation in Austria and Germany, and the success achieved warrants the belief that this method of operation will soon begin to supersede that of the steam engine. *See* **Rolling Mill Engines.** It has many advantages besides that of economy. The condition which is most favourable to its adoption is that of firms who have their own blast furnaces, the waste gases of which can be utilised for driving gas engines for generating electricity. But when this condition is not present, the erection of a generating plant will be found economical, because less steam is wanted for producing the quantity of electricity required for motor driving than for driving a steam engine. The latter is very wasteful, due to the rapid reversals and intermittent working. By substituting the motor drive, a great reduction can be made in the number of boilers required, with saving in cost of upkeep and in space. In the installation at the Hildegarde works in Austrian Silesia; of fifty-four boilers originally in use, seventeen only were retained when the greater part of the works had been converted to electric driving, and these may be reduced still further. A steam turbine generating plant was installed here for local reasons in preference to a gas engine. The original reversing steam engine ran at 100 revolutions per minute, the speed of the mill was increased to 120 revolutions when the motor drive was substituted.

The difficulties due to the excessive peak loads corresponding with rolling and reversing are surmounted by a flywheel balancing plant, on the Ilgner system, which reduces them to a comparatively low and straight load line. In this, a three-phase motor is coupled through two heavy flywheels to two continuous current generators flanking the flywheels. These wheels weigh 26 tons each. The result of the introduction of the balancing system is economy in current used. Though the rolls may take momentarily as much as 8,000 or 10,000 HP., the energy taken from the electric mains is only about one-tenth of that. The load varies from zero to 8,000 HP. in from two to three seconds, the rolls passing from a state of rest to 110 revolutions in that period. The controlling apparatus is extremely easy to manipulate, comprising only the to-and-fro movement of a single lever. As the control is exercised through the balancing system, the current which has to be controlled never exceeds 150 amperes, against from 8,000 to 10,000 amperes, which is the strength of the main current. The method of working out the electrical details may be studied in a paper by Mr Bigge read before the Iron and Steel Institute on 9th May 1907.

Revolving Furnaces. — *See* **Rotary Puddling Furnaces.**

Revolving Tool Box.—*See* **Tool Boxes.**

Rhomboid.—A rhomboid is a parallelogram

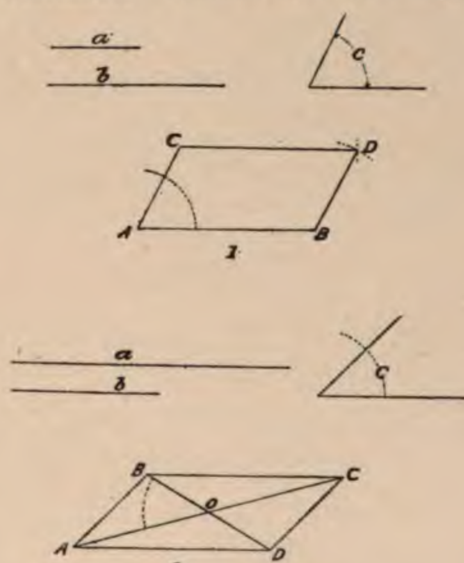


Fig. 208.—Rhomboid.

which has its opposite sides equal and parallel, but its angles are not right angles. In any rhomboid,

Area = base × perpendicular height.
Base = area ÷ perpendicular height.
Perpendicular height = area ÷ base.

Or, Area = product of any two sides × the natural sine of their included angle.

To construct a rhomboid, Fig. 208 (1), having given two sides, a, b, and their contained angle c. Make AB $= b$, and at A make an angle equal to the given one, c; draw AC $= a$. From B with radius = AC describe an arc, and from C with radius equal to AB cut this arc. Join CD, BD.

To construct a rhomboid, having given the two diagonals, a and b, and the angle between them, Fig. 208 (2). Bisect both diagonals. At a point O make an angle AOB equal to the given angle, and make OA = half a, and OB = half b. Continue these lines through O so that OC = OA and OD = OB. Join the points A, B, C, D.

Rhombus.—A rhombus is a parallelogram which has all its sides equal but its angles are

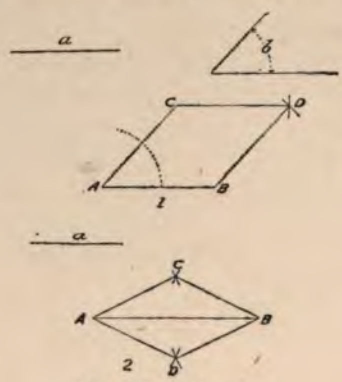


Fig. 209.—Rhombus.

not right angles. The mensuration of the rhombus is identical with that of the **Rhomboid**.

To construct a rhombus, Fig. 209 (1), having given one side, a, and angle, b. Make AB $= a$, and at A make the angle CAB $= b$. Draw AC $= a$. With B and C as centres and radius AB describe arcs cutting each other at D. Join BD, CD.

To construct a rhombus, having given one side, a, and a diagonal AB, Fig. 209 (2). With A and B as centres and a as radius describe arcs each side of AB at C and D. Join AC, BC, AD, BD.

Riddle.—*See* **Sieve**.

Ring.—To find the volume of a solid ring, multiply the area of a cross section by the length of the ring. A cross section is shown by dotted lines in Fig. 210. The length is the circumference of a circle passing through the


Fig. 210.—Ring.

centres of all the cross sections. The strength of thin rings to resist internal pressure is obtained by regarding the pressure in pounds per square inch as exercised across the central diametral plane, and resisted by the thickness of metal in that plane. But this does not hold good with thicker rings, because the outer layers are not strained by stretching so much as the interior ones are, which is clearly seen to be impossible. Hence difficult problems arise in the design of built-up guns, and to a lesser extent in hydraulic cylinders, which involve highly mathematical treatment.

Rip Saw.—A rip saw is intended exclusively for cutting wood in line with the fibres, and this necessitates making its teeth of a form unsuitable for cross-cutting. Rip saws are of two classes—machine saws intended for ripping, and hand saws for the same purpose. The latter are comparatively little used, as small amounts of ripping can be done with an ordinary cross-cutting hand saw, and ripping is seldom done by hand if a machine saw of any kind is available. The teeth of rip saws are larger and have less set than those for cross-cutting. They are also given more rake or forward slope than a cross-cut. This enables them to rip more rapidly but unfits them for use across grain, where they would be continually catching, with disastrous results to the truth of the blade. Machine saws, which are either of the band or circular type, also have larger teeth with less set and more rake when intended for ripping. Hand rip saws are of two kinds. There is the rip saw proper, and a smaller variety called a

half rip, the latter being suitable for light work and more generally employed than the full size rip.

Riser, or Air Gate.—An opening which nearly, or often exactly resembles a small pouring basin, but which is provided for the free escape of air from a mould at the time of pouring. It may be adjacent to the pouring basin, but when practicable it is better to locate it as far away as possible. In many cases several risers are employed.

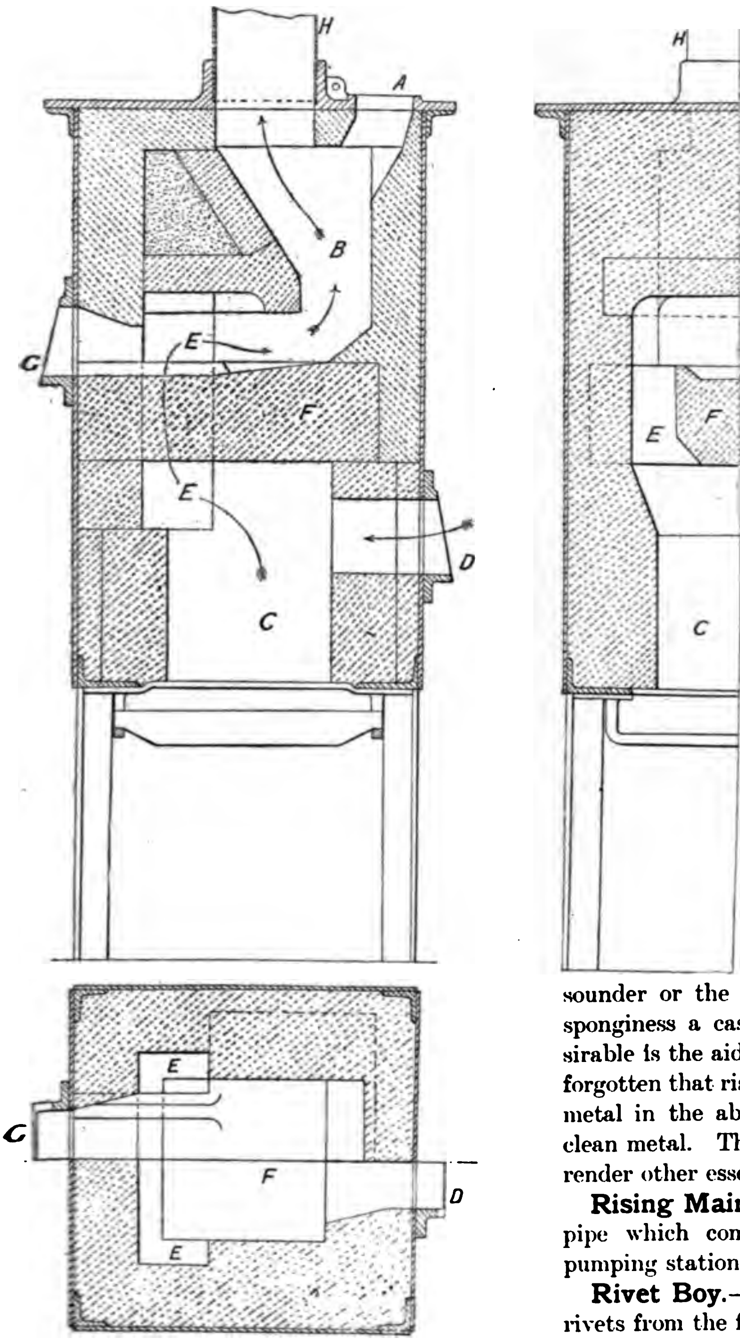


Fig. 211.—Rivet Furnace.

When pouring is nearly done, air charged with particles of carbon or other matters can be seen beginning to come out of the open risers. This is followed by the metal, which finds its level with that in the pouring basin. The riser is therefore a safety valve from which air and gases escape which would otherwise remain in the mould, causing blow-holes, or straining. The air is carried onwards by the in-flowing metal until it reaches the risers. Very often, in large work especially, a clay plug is laid on the mouth of the riser to prevent a too sudden rush of air through the mould.

The number of risers on a mould varies with different men's ideas. It is good practice to put a riser over every high part, or if the high parts are extensive to put several on. The question is one for judgment and experience. The sounder or the more free from blow-holes and sponginess a casting is required, the more desirable is the aid of risers. But it must not be forgotten that risers will not ensure clean sound metal in the absence of proper venting, or of clean metal. They are valuable aids, but do not render other essential precautions unnecessary.

Rising Main.—The first portion of delivery pipe which comes direct from the pumps at pumping stations.

Rivet Boy.—The lad who takes the heated rivets from the furnace and passes them to the riveters.

Rivet Forge.—A small portable forge used in outdoor work for heating rivets where the volume of work would not be sufficient for the use of a rivet furnace.

Rivet Furnace.—A small furnace used for heating supplies of rivets for closing up. It is usually a square structure of sheet iron or steel on legs, or portable on wheels, brick-lined, having a tall chimney, and fired with small coal. The fuel is burnt on a grate below the rivet bed or beds, so that the hot gases only pass over the latter on the way to the chimney. The rivets are inserted and taken out through a small doorway. Gas is used as a fuel in some cases. A furnace measures about 2 ft. square by 4 ft. or 5 ft. high.

In a recent type termed the *cupola*, by Messrs Henry Berry & Co., Ltd., the rivets descend automatically from the colder part of the furnace where they are inserted, to the hottest where they are taken out. 3,000 ¾-in. rivets can be heated in it in a day, with the expenditure of about 2½ cwt. of coal. This cupola rivet furnace is shown in sectional views by Fig. 211. It is 2 ft. square, by 5 ft. high, and is made of steel plate, lined with fire-brick. The chimney, 7 in. diameter, is 17 ft. high. The whole is supported on legs of angle section. The design of the furnace is such that the rivets are gradually heated in their descent, and the products of combustion are cooled by their passage upward through the rivets. The rivets are inserted through the door A, a proper charge being when the hopper B is about half full. No rivets are put in until the furnace has heated the brick-work to a red heat. The furnace C is kept charged up to the level of the door D. The products of combustion, as indicated by the arrows, pass up round the ports E by the side of the solid fire block F, on which the rivets lie to be removed through the taking-out door G. The chimney H is furnished with a damper at the top, which should be closed when the furnace is not in use.

Overheating of rivets, and heating them in a dirty furnace is a fruitful cause of bad work. The presence of scale due to overheating, and to slag due to dirt prevent the contact of metal which is essential to close tight joints. Rivets scale if overheated, and if allowed to come into direct contact with fuel, and a rivet thus encased with scale or dirt should not be allowed to enter its hole. The scale, if present, should be struck or brushed off first, because it impairs the closeness of the joint.

Riveting—*Rivet Joints.*—Examples of the typical joints used are shown in Figs. 212 and 213. There are two methods by which the strength of riveted joints is arrived at, one by experiment, the other by calculation. In practice the latter is of less direct value than the former. The relative strengths of all kinds of riveted joints have long been settled by experiments, and boiler-makers and platers have tables of the proportions for the different types of joints used. These tables would not always accord strictly with calculations, neither is it necessary that they should do so. Practical considerations regulate their construction, as in other matters, and uniformity of dimensions, simplification of work, and ample margin of strength are consulted. Actually, riveted joints seldom fail except when there has been bad workmanship, or bad subsequent treatment. When a boiler fails it usually fails through the plates. If rips occur, that is due to grooving or furrowing, and this is owing not to the weakness of the joint itself, but to some faulty principle in its design, in consequence of which the plates contiguous to the joint are subject to incessant alterations of stress by alternate heating and cooling.

A riveted joint may be considered as a chain made up of two kinds of links, one being *rivet section*, the other *plate section*. That is, the collective area of the row of rivets in the joint will form one link of the chain, and the collective area of those portions of the plate section left between the rivet holes will form the other link of the chain. Obviously the strength of the chain is no greater than that of the weaker link, which generally happens to be that of the plate section. Theoretically a joint should be so designed that the strengths of rivet and of plate section should be alike. But rivets are made larger than necessary, because the size of their holes is regulated by the power of the punch, and by the necessity for making the plates tight, and so it happens that in the rupture of a joint the plate nearly always tears,

while rivets are seldom shorn off. In fact the rivet section may often be twice the strength of the plate section.

Failure of a riveted joint may occur along the line of rivet centres, Fig. 214, A. This is one of the most frequent occurrence, and indicates what is usually the weakest part of the joint. Fracture may occur by the metal rupturing in front of the rivet, Fig. 214, B, the fracture being like that of a beam fixed at each end, in this

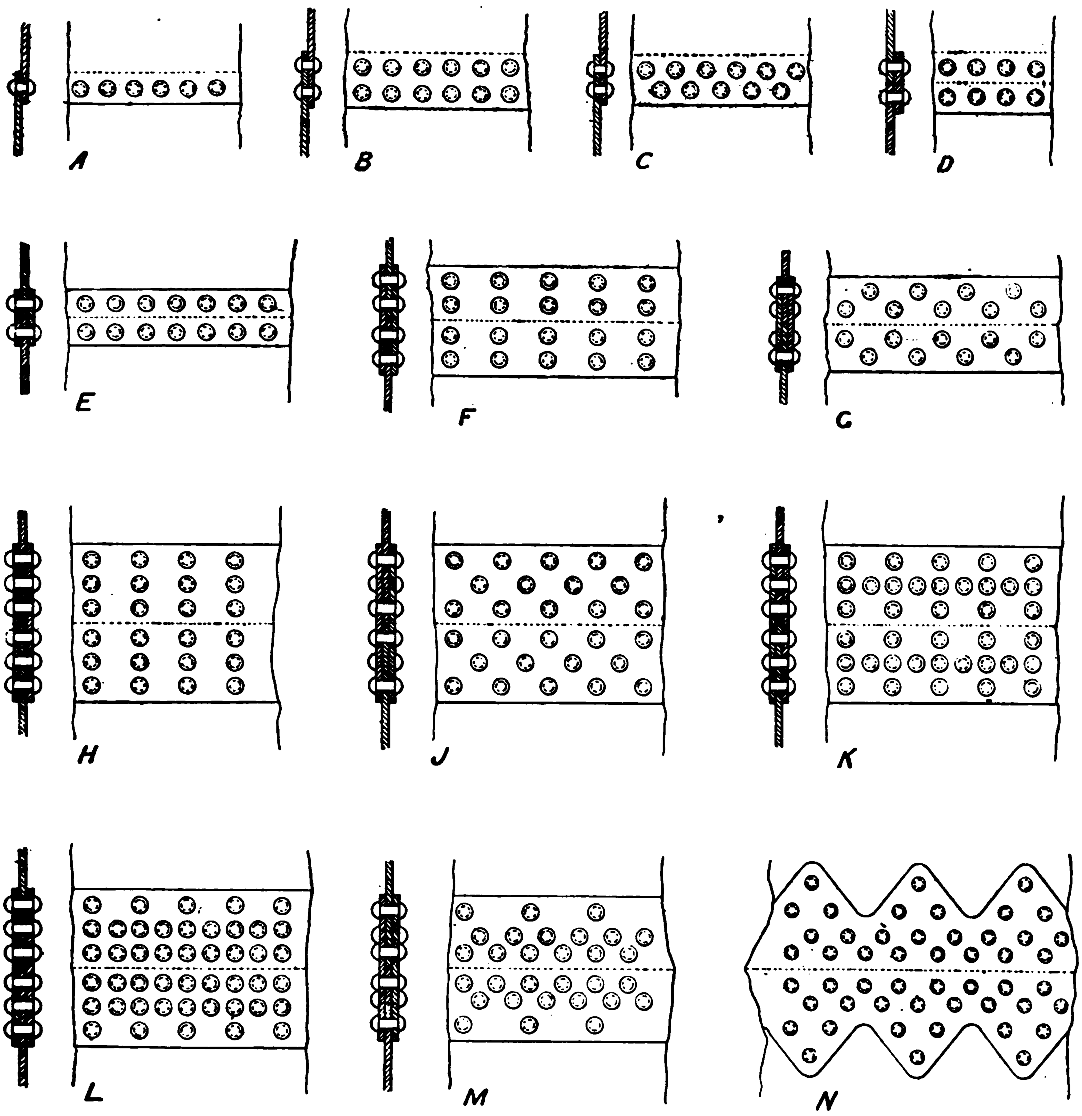


Fig. 212.—Riveted Joints.

A. Single-riveted lap joint. *B*. Double-riveted lap joint (chain riveting). *C*. Double-riveted lap joint (zigzag riveting). *D*. Single-riveted, single butt strap. *E*. Single-riveted, double butt strap. *F*. Double-riveted, double butt strap (chain riveting). *G*. Double-riveted, double butt strap (zigzag riveting). *H*. Treble-riveted, double butt strap (chain riveting). *J*. Treble-riveted, double butt strap (zigzag riveting). *K*. Treble-riveted, double butt strap (each alternate rivet omitted in inner and outer rows). *L*. Treble-riveted, double butt strap (chain riveting), each alternate rivet omitted in the outer row. *M*. Treble-riveted, double butt strap (zigzag riveting), each alternate rivet omitted in the outer row. *N*. Quadruple riveting, used on some of the largest marine boilers.

case at adjacent rivets, and loaded at the centre by the rivet at which fracture occurs. This happens if the rivet holes are placed too near to the edge of the plate. In practice it is usual

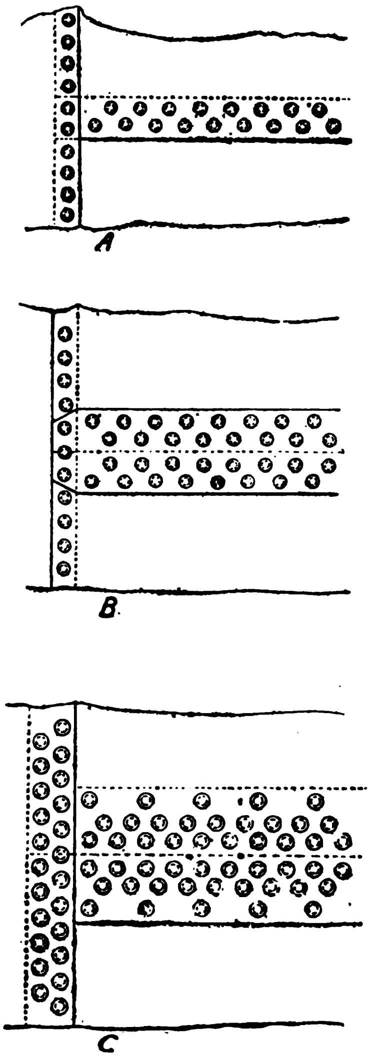


Fig. 213.—Riveted Joints.

A. Double-riveted longitudinal lap seams, and single-riveted circular seams in boilers. *B*. Double-riveted longitudinal butt joints, with single-riveted circular lap joints in boilers. *C*. Treble-riveted longitudinal butt joints, and double-riveted circular lap joints in boilers.

to make the distance from the centre of rivet to the edge of the plate not less than the diameter of the rivet—it may equal one and a half times that diameter. In steel plates the distance need not be quite so much as in iron. In any case if too much lap is allowed it is not so easy to make a tight joint by caulking,

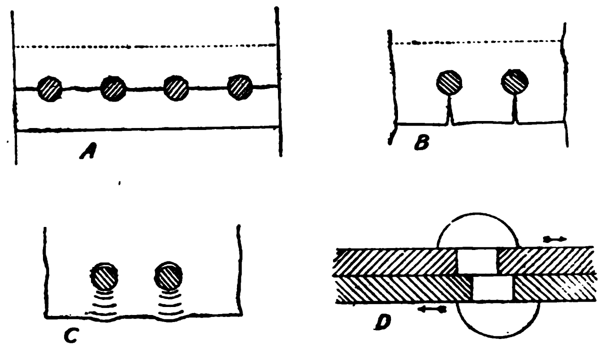


Fig. 214.—Methods of Failure of Riveted Joints.

because of the greater elasticity of the joint. Professor Kennedy, in his researches on the Riveting Committee of the Institution of Mechanical Engineers, demonstrated that the margin of a riveted seam need never be greater than the diameter of the rivet. This was deduced from experiments with varying margins, in every one of which the rivets were shorn through first. Fracture of a rivet joint may occur by crushing of the plate in front of the rivet, Fig. 214, C. But such a mode of fracture does not occur, because the bearing strength is always in excess of the tensile and shearing strength. Lastly, shearing of rivets may occur, Fig. 214, D, in a joint, if the rivets are too small, or spaced too widely, causing their resistance to shearing to be less than that of the tensile resistance of the plate. But such a method of fracture rarely, if ever occurs in steam boilers, because excessively small holes cannot be punched, and because steam-tight joints cannot be made with widely spaced rivets.

Besides the equality desirable in the strength of rivet section and plate section the following theoretical considerations are to be noted.

Taking the resistance of the plate in front of the rivet to crushing, due to the intensity of the bearing pressure of the rivet: the bearing surface equals the diameter of rivet multiplied by the thickness of the plate:—

Let c = the ultimate resistance of the plate to crushing; t = the thickness of the plate; d = the

diameter of rivet; C = the ultimate resistance per square inch of the plate to crushing.

Then $c = d \times t \times C$.

For the ultimate resistance to single shearing; let s = the ultimate resistance to single shearing, d = the diameter of rivet; S = the ultimate resistance per square inch to single shearing.

Then $s \times d^2 = \cdot 7854 \times S$.

When the crushing resistance of the plate and the shearing resistance of the rivet are equal, then

$d \times t \times C$ should equal $d^2 \times \cdot 7854 \times S$.

From this relation the diameter of a rivet for a given thickness of plate is deduced.

The ultimate tensile strength of the plate section between rivet holes is obtained thus:—

Let t_s = the ultimate tensile resistance of the section; t = the thickness of the plate; p = the pitch of rivets; d = the diameter of the rivets; T = the ultimate tensile resistance of the material per square inch.

Then $t_s = t \times (p - d) \times T$.

Hence when the shearing resistance of the rivets and the tensile resistance of the plate are equal, then

$$d^2 \times \cdot 7854 \times S = t \times (p - d) \times T.$$

When there is more than one row of rivets, the area of one rivet will be multiplied by the number of rows of rivets. With double-riveted lap joints, and with double-riveted butt joints with single straps, and with single riveted butt joints with double straps,

$d^2 \times \cdot 7854$ would become $2 \times d^2 \times \cdot 7854$.

With double-riveted butt joints with double straps, in which the rivets are in double shear, we should have

$$4 \times d^2 \times \cdot 7854.$$

The percentage strength of plate left between rivets in the greatest pitch in any given joint is obtained by subtracting the diameter of the rivet from the pitch of the rivets, and dividing the result by the pitch thus—

$\frac{(p-d)}{p}$, or as it is usually put, $100 \frac{(p-d)}{p}$.

To find the percentage strength of rivet section as compared with solid plate. Multiply the area of one rivet in square inches by the number of rivets n in one row (the greatest pitch) and by 1 for lap, or single butt strap joints; or by 1·75 for double butt strap joints, and divide the result by the pitch of the rivets, multiplied by the thickness of the plate, thus—

$$\frac{d^2 \times \cdot 7854 \times n \times 1 \text{ or } 1\cdot 75}{p - t}.$$

With regard to the pitching of chain, and zigzag rivets, the distance from centre to centre of rivets wherever measured must not be less than twice the diameter of the rivets. It is better to have the diagonal measurement in the zigzag arrangement in excess of this. According to Professor Kennedy, the net section of metal between rivets measured in the zigzag direction should be from 30 to 35 per cent. of that taken between parallel rows. So that the diagonal pitch would be about $\frac{2p + d}{3}$.

The Board of Trade rules for the distance between the centres of the rows of rivets in chain and zigzag arrangements are—

Chain $2d$

Zigzag $\frac{\sqrt{(11p + 4d)\ (p + 4d)}}{10}$.

Butt Joints.—These are designed to prevent the bending which occurs in single-riveted joints under stress, and especially in cylindrical work. Such joints have *strips*, or *straps*, riveted across the abutting joint, so keeping the abutting parts in one plane. They are fitted with *single*, or *double* covering straps. The covering straps for butt joints should be cut from plates, and not from bars, and the strips for longitudinal seams, if in iron, should be cut across the grain, so that the fibre shall be in the strongest direction to resist the greater stress. There are several rules given for the thicknesses of butt straps. Single straps must be slightly thicker than the plates which they connect, double ones thinner.

In riveted joints, if the rivets are pitched or spaced too closely, then the plate will become torn asunder while the rivets remain intact. If pitched too far apart the rivets will become shorn while the plate remains intact. If the rivets are pitched so that the plate section and rivet section are of equal strength, then the effects of corrosion operating more effectually upon the plate than upon the rivet will in time

cause the plate section to become weaker than the rivet section. Moreover, the plate may have already suffered by reason of the work done upon it, as in punching, or rolling, or hammering, or drifting, and if so allowance must be made for the weakening effects of these operations. Then as regards the absolute strength of plates and rivets, the first is subject to tensile, and the second to shearing stress. In iron these stresses are practically alike, that is, if it takes 20 tons per square inch of stress to break a plate by tensile stress, it will take also 20 tons per square inch to sever a rivet by shearing stress. But with steel the tensile and shearing stresses are not alike, but while the tensile strength equals 28 tons, the shearing only equals 23 tons.

The clearest method of representing in a graphic manner the relation of a riveted joint to the solid plate is shown in Fig. 215, an

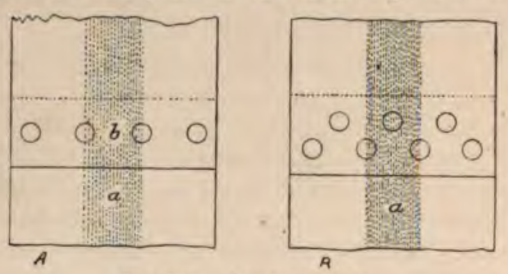


Fig. 215.—Riveted Joints.

illustration due to a writer in the *American Machinist*. Let (A) the shaded portion *a* represent a width equal to the pitch of the rivets in a single-riveted lap joint. The strength of the joint is not, however, represented by *a*, but by the width *b*, and by the area of the rivet. Obviously, too, a single rivet has to hold the width *a* securely, and therefore the rivet must be of equal strength with the section *b*. Hence the dictum that in a theoretically perfect riveted joint the plate section and the rivet section should be of equal strength. Again, a similar figure (B) will show graphically the relative proportions of rivet and plate in a double-riveted joint. Here we have the width *a* as before, but it is held together with two rivets instead of one.

It is because the rivets can be pitched farther apart in double-riveted joints than in single-riveted joints that the former is stronger than the latter. It has often happened that the spacing in double-riveted joints has been nearly, and even quite as close as in single-riveted joints, and then the advantage of double riveting has been lost. A large excess of rivet section has been obtained at the sacrifice of plate section, and as the strength of a joint is measured by that of its weakest part, the plate section left between the rivet holes determines in such a case the strength of the joint.

It is impossible to estimate the strength of a riveted joint *ab initio*, that is purely as a question of calculation apart from the aid afforded by direct experiment. A riveted joint is subjected to stresses which are not uniformly distributed in the sense in which a directly tensile or compressive stress is distributed through the section of a plate or bar. The stresses are unequal, being more intense in some parts of the joint than in others, while the several parts will be subject to increase or diminution of stress by the action of loads. Consequently a riveted joint will fail, not by the maximum stress which a given part will endure, but by an average stress which is lower than the maximum, and this can only be determined by experiment. But in a properly conducted series of experiments on riveted joints the strength of each element has to be first determined accurately. In no other way is it possible to arrive at correct conclusions as to the strength of plates, the tensile and shearing strength of rivets, the effect of punching, reamering, and drilling, on the tenacity of plates and bars, or to gather definite conclusions as to the effect of the frictional resistance of the riveted plates.

Friction.—It has been considered that the friction between the surfaces of riveted plates should count for something in estimating the strength of a riveted joint to resist slipping under stress. But long ago experiments instituted by the Board of Trade for the use of their surveyors, and embodied in their 1881 Report, dispelled this idea. It was shown then (page 32) that when a joint is tested to destruction, it gapes, the plates opening along the edges. In the case of 1-in. plates with treble-riveted lap joints

the opening amounted sometimes to as much as $\frac{5}{16}$. Even in the case of riveted joints fitted with double butt straps, the bending of the rivets caused the joints to open. The friction of newly riveted plates due to the contraction and nipping power of the rivets in cooling varies roughly according to experiments from 4 to 5 tons per square inch of rivet section. But in a long rivet the contraction will strain the metal beyond the elastic limit. In short rivets, however, not subject to bending stresses, a small allowance may be safely made for friction, say about 3 tons per square inch of rivet section. But in a joint subject to much stress, causing leaky seams and stressing of the rivets, nothing can be allowed for friction.

Professor Kennedy's experiments on riveted joints undertaken for the Institution of Mechanical Engineers showed that the visible slip of a riveted joint occurs at a point very much below the breaking load, but by no means proportional to that load, and that it depends on the number and size of rivets in the joint, and on the stiffness of the joint. Hydraulic riveting, by exercising pressure on the joint, tends to delay slip. Slip is due to the commencement of shear in the rivets.

Strength of Joints.—The old ratios of Fairbairn's for the relative strength of riveted joints are — Solid plate 100, double-riveted joint 70, single-riveted joint 56. The value of riveted joints, as calculated by formulæ, and as ascertained by actual tests, do not coincide. Thus in the experiments on Weardale steel, recorded in the 1885 Memorandum, issued by the Board of Trade for the use of their surveyors, the calculated and the actual tests varied as follows :—

Using the formulæ for lap joints—

$$\frac{\text{Width of plate - Sum of diam. of rivets in line}}{\text{width of plate}} \times 100.$$

In $\frac{1}{2}$-in., $\frac{3}{4}$-in., and 1-in. joints in which holes were punched, there were losses of strength by experimental test as compared with calculated strength, of 12·7, 28·9, and 28·0 per cent. respectively. In $\frac{1}{2}$-in., $\frac{3}{4}$-in., and 1-in. joints in which the holes were drilled, there was a gain of strength in the first two respectively of 1·9, and 7·0 per cent., and a loss in the third of 3·8 per cent.

Professor Kennedy's experiments showed that single-riveted lap joints, taking $\frac{3}{4}$-in. steel plate, cannot have an efficiency as compared with the solid plate much exceeding 50 per cent. The only way in which the strength could be increased would be by increasing the bearing pressure, which means increased size of rivets, and larger spacing, but this is not practicable. The objection to increasing the size of rivets is that their sectional area to resist shearing is increased in proportion to the square of their diameter, while the strength of plate section is increased only as the distance between the holes.

In proportioning the riveted joints of a girder, the rivets may be pitched on the reasonable supposition that the plate and rivet section will have the same relative strength throughout all the life of the girder. Not so in a steam boiler, for here it is the plate section alone which will be likely to suffer and waste by wear and tear.

Errors in workmanship always tend to weaken plate sections in relation to rivet section. The sectional area of a rivet always remains intact, however severe the treatment to which the plates are subject. But the plate area is diminished during working by drilling, or punching the holes larger than the rivets; or if punched, by drifting the holes to pull them fair into place, and if very rough drifting is done, by cracking the plates. In boilers at work, severe stressing, and corrosion still further weaken the plate section. For these reasons it is desirable to pitch rivets as widely as possible consistently with tight joints. In this respect the practice of the present day is better than that of the past, when rivets were pitched closely in order to secure tight seams, without regard to the effect of this practice in diminishing the plate section and therefore weakening the seams.

Drifting.—It is idle to say that the use of the drift ought to be abolished, since without that very much trouble would be involved in putting work together. When holes are punched or even drilled with the plates apart, then, however carefully the work might have been done, the holes will not come perfectly fair, and if they do not, the insertion of a few drifts at intervals in order to pull the holes into line is

necessary. There is a use and an abuse of the drift—the first is legitimate, the second reprehensible. In many cases it is just as necessary to insert drifts as tack bolts, and what a foreman has to do is to draw the line between use and abuse.

The evil of drifting in stressing boiler plates has perhaps been somewhat overrated. In good plates the evil does not lie so much in inducing excessive stress as in the fact that it places the holes in diagonal positions relatively to each other, and that the rivet consequently does not take a fair bearing throughout its length, nor under the head. Although heavy drifting will crack inferior plates, it must be excessively heavy to crack the ductile plates which alone should be used for steam boilers. One of the forge tests for iron and steel consists in drifting out a punched hole to a larger diameter without cracking. The evil of drifting comes in when the holes are very bad, say anything over $\frac{1}{32}$ out. To talk about reamering out such holes, and inserting larger rivets is absurd. The job would be more costly, and the plate section would be weakened.

Riveting Cranes.—The large variety of riveting operations done in boiler shop, bridge, and girder work have been the cause of the development of several distinct types of cranes for sustaining and traversing the portable riveting machines over and about the work. These include fixed and portable designs. The principal types used are swinging jib cranes, or independent portable cranes with swinging jibs. Overhead travellers, and overhead tracks are also utilised. But the essential difference between common cranes and those used for riveting is that the latter have some attachments or provisions for conveying the pressure water to the portable machines suspended from them. Otherwise the methods of building up the crane framings do not differ materially from those of ordinary cranes of similar designs. The riveter is racked along by an ordinary carriage or jenny, lifted and lowered by an hydraulic cylinder and ram, termed a *telescopic lift*, or *puller*, which may be indifferently disposed vertically, or horizontally. In a few designs the cylinder is located in the post, but generally it is suspended, and situated vertically directly over the portable machine; or horizontally on the carriage which traverses the machine. The pressure water is brought to the top or bottom of the post through a swivel joint. A pipe comes from this joint to a point somewhere about midway along the jib. From this, jointed walking pipes, the joints of which are packed with cup leathers, convey the water to the cylinder. A coiled copper pipe with sufficient flexibility to follow the portable riveter conveys the water to it. Around this general design there are many variations to suit all conditions of working.

A wall jib crane with suspended riveter is shown in Fig. 216, Plate XIV. The pillar, which is made of cast steel, may be attached either to a wall, as seen, or to a column, by trunnion bearings at top and bottom. The horizontal jib, built up of two channels back to back, and tied at the end to the top of the pillar by wrought-iron rods, supports the travelling carriage, which is racked along by dependent chain and gearing. The quadrant hanger from which the riveter is suspended is attached to a chain passing up around the pulleys of a horizontal hydraulic cylinder, and the ram of the latter is moved in or out to alter the height of the riveter, a range of 7 ft. being possible. A coiled copper pipe admits of flexibility of connection between the riveter and the carriage, where the end of the jointed walking pipe, which is coupled to the horizontal pipe on the jib, is situated.

Fig. 217, Plate XIV., illustrates a single rail type of crane, in which a travelling frame takes the place of the wall in the previous example, the frame running by ground wheels on a rail at the bottom, and being steadied by rollers at the top, bearing against an H girder. The frame is travelled by hand gear. The water is conveyed from pipes set a little below the floor level up to the jib, and to the riveter in the same manner as described in connection with Fig. 216. An enlarged view of a riveter with its carriage is given in Fig. 218, Plate XV.; the construction and mode of operation is the same as described above.

Riveting Machines.—The growth of these machines is one of the remarkable chapters in engineering practice. Steam was the agency

Fig. 218.—Riveter with Hydraulic Lifting Cylinder. (Henry Berry & Co., Ltd.)

Fig. 223.—Fixed Hydraulic Riveter. (Musgrave Brothers.)

Fig. 225.—Furnace Mouth Riveter. (Fielding & Platt, Ltd.)

Fig. 227.—Bear Type of Riveter. (Musgrave Brothers.)

Fig. 229.—Hinged Riveter. (Musgrave Brothers.)

Fig. 230.—Pneumatic Deck Riveter. (The Consolidated Pneumatic Tool Co., Ltd.)

To face page 216.

first used, but that has nearly fallen into disuse since the growth of the hydraulic and pneumatic systems. Fairbairn invented the steam riveter. To Ralph H. D. Tweddell is due the honour of the inception and development of the hydraulic system, and to Mr Allen that of the pneumatic. But the hydraulic and pneumatic systems have been extended greatly to include many designs for special functions which were deemed im-

Stationary, or Fixed Riveters.—These represent the older type which preceded the portable designs. The majority are of vertical form, that is the framing is so arranged that the work to be riveted is lowered vertically between the ram and the riveting dies, the axis of which lies in a horizontal plane. These machines are used for riveting boiler shells, and shell end plates, pipes, and cylindrical work generally.

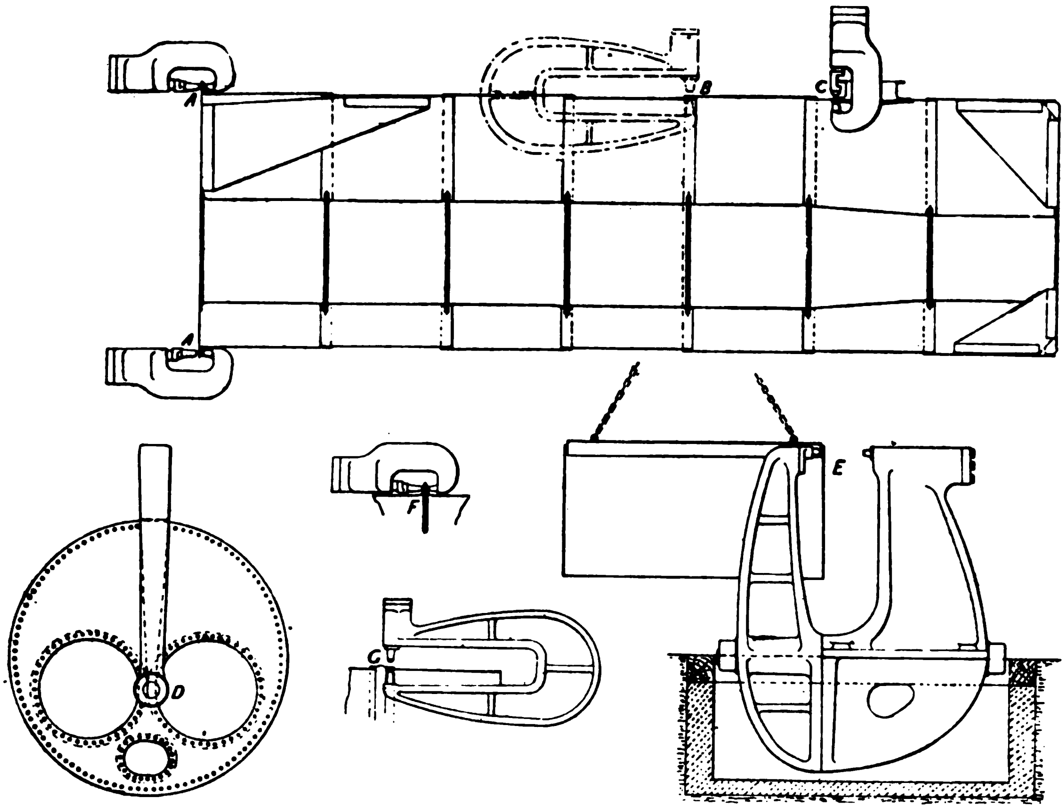


Fig. 219.—Hydraulic Riveting Applied to Lancashire and Cornish Boilers.

A, A. Riveting front plate to shell. *B.* Riveting boiler shell in horizontal position. *C.* Riveting manhole to shell. *D.* Riveting flues to front plate. *E.* Riveting shell and back end plate, &c. *F.* Riveting Adamson flue seam. *G.* Riveting Bowling flue seam.

practicable a few years since, until now there are few sections of boiler shop work, or constructional riveting which cannot be reached by some form of machine.

The illustrations, Figs. 219-221, show in a very clear manner how the various portable and fixed riveters are applied to boilers of different types; the drawings are from the practice of Messrs Henry Berry & Co., Ltd.

The two leading particulars of a riveting machine are the depth of gap, and the amount of pressure exerted in closing the rivet. As these vary, so also do some of the details of design vary. In the smaller machines the framing is generally in one piece, in cast iron. In larger sizes it is frequently of cast steel. In the largest it is usual to make the framing in two portions; the body or main standard of cast iron, either

strongly ribbed, or of closed box section; and the other portion, which is termed the *holder up*, or *hob*, of cast steel, or of forged steel. The first is the more common. The main frame and the hob are planed to fit face to face with a shoulder, or are united by two very massive bolts passing right through both castings. When the hob is made in forged steel it is either flat, or oblong in cross section, or of cylindrical tapering form from base to top. On tons, and one of 150 tons to 60 tons, and others in similar proportions.

In this main design there are three well-marked variations. In one, the closing die instead of being situated centrally in its boss is much nearer the top than the bottom portion of the boss, and is termed the *flush top design*. It is used for doing a class of work which cannot be done by the ordinary type, in which the boss standing out, renders it impossible to bring

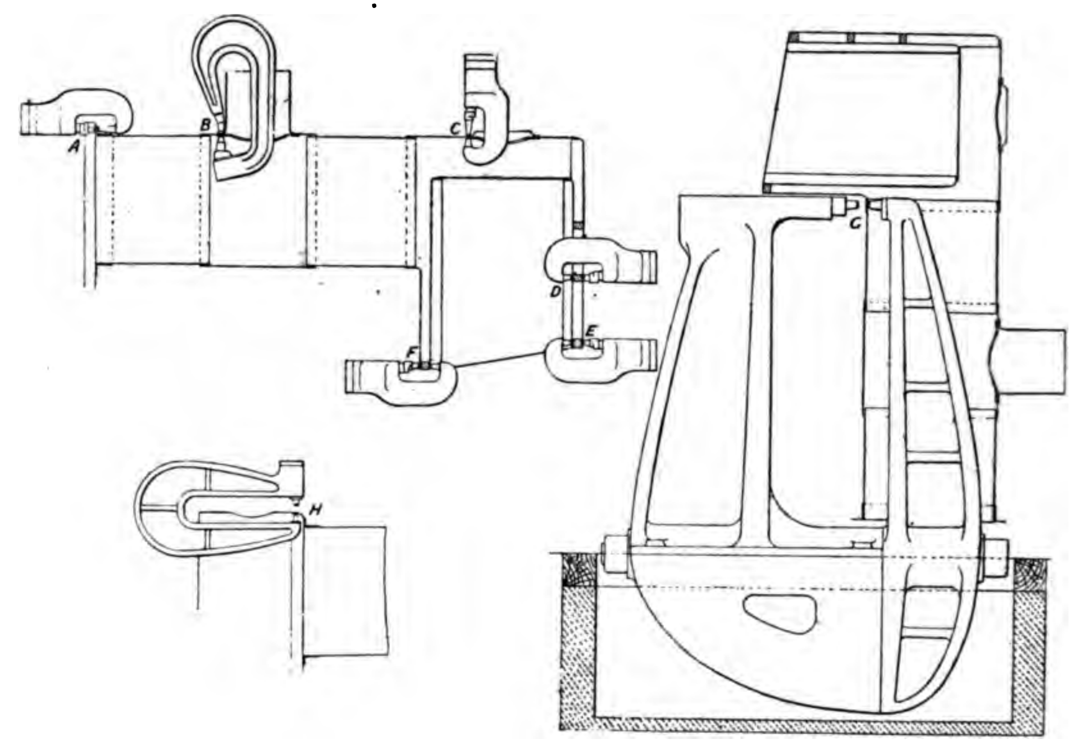


Fig. 220.—Hydraulic Riveting Applied to Locomotive Boilers.

A. Riveting tube plate to barrel. *B.* Riveting dome to barrel. *C.* Riveting safety-valve seating to barrel. *D.* Riveting round fire-box door. *E, F.* Riveting round furnace bottom. *G.* Riveting barrel, &c. *H.* Riveting smoke-box to tube plate.

one or other of these designs all standard stationary riveters are built. The depth of gap ranges from 3 ft. up to about 12 ft. at extremes. The power exercised on the rivet at the moment of closing will range from 15 tons in the smallest to 150 tons in the largest. But the operator is able to vary the pressure at will. Thus in the Fielding & Platt machines, a machine with a maximum power of 70 tons may be varied to a minimum of 30 tons, one of 100 tons to 40 the closing die up to the line of rivets. It is used specially in the boilers of locomotive and portable engines, for riveting the throat plates of the fire-boxes to the barrels. *See* Figs. 219 to 221. In another design, a top lever is fitted to the riveting slide, and so pivoted to the slide and to the framing with arms, that it closes a rivet in the vertical direction, Fig. 221, a die holder to correspond being fitted to the top of the hob. This is used for riveting

the outer fire-box plates to the wrapper plates. The third variation is the *plate-closing* riveter, which closes and holds the plates together, under strong pressure before, and while the rivet is being closed. It was designed for dealing with the thick plates of marine boilers, which range from 1 in. to 1½ in. in thickness.

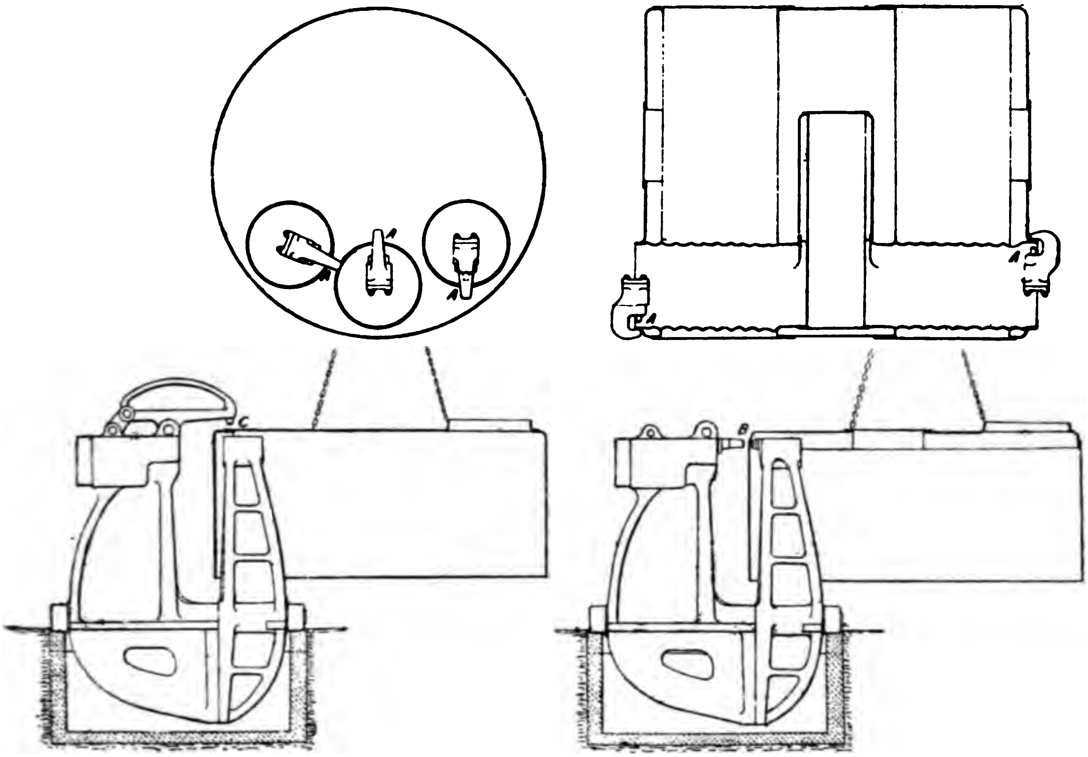
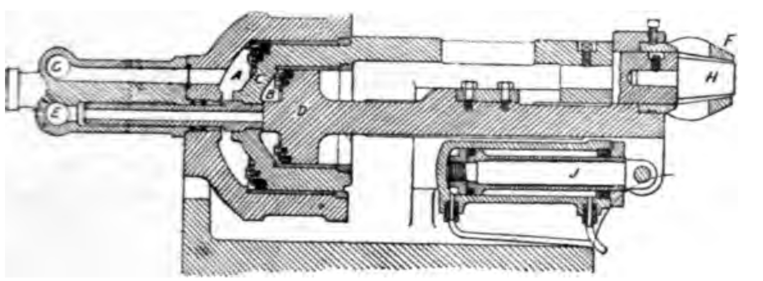


Fig. 221.—Hydraulic Riveting Applied to Marine Boilers.

***A*, *A*, *A*, *A*, *A*. Riveting furnace flues. *B*. Riveting shells and end plate with end plate flanged. *C*. Riveting shells and end plate with shell flanged.**



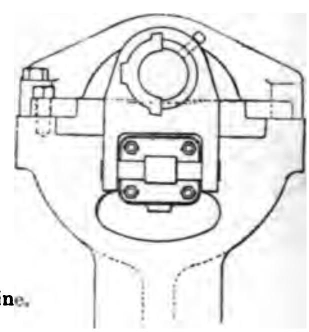


Fig. 222.—Mechanism of Plate-Closing Riveting Machine.

What happens when a rivet is turned in plates which do not make a close fit, is that a portion of the rivet becomes squeezed out, forming a fin, or annulus, termed "washering," between the plates. The plate-closing device avoids this. The details of this for a 100 ton riveting by Messrs Fielding & Platt are shown in Fig.

222. Here A is the riveting cylinder, B the plate-closing cylinder contained within A. C is the movable riveting ram, sliding within the cylinder A, and D is the plate-closing ram sliding within C. E is the valve from the accumulator, which when opened by a lever produces the forward movement of the ram D, which carries at the farther end of its stem the annular closing tool F, fitted and held within it by a set-screw. The valve G being then opened, the ram C is thrust forward, with the cupping or riveting tool H at its end, held with a set-screw. The effect of admitting water inch, varying closing pressures may be given on rivets, of 30, 50, or 80 tons as desired. A plate-closing device is fitted on the holding-up side. Water is saved by employing a small ram on the back of the head to move up the main ram, the cylinder of the latter being meanwhile filled with water from an overhead tank; when the snap reaches the rivet, pressure water acts on the ram and effects the squeeze. A stop-valve is provided, to avoid the necessity of closing down the pump and accumulator while re-leathering the machine, so that other riveters, &c., are not interfered with.

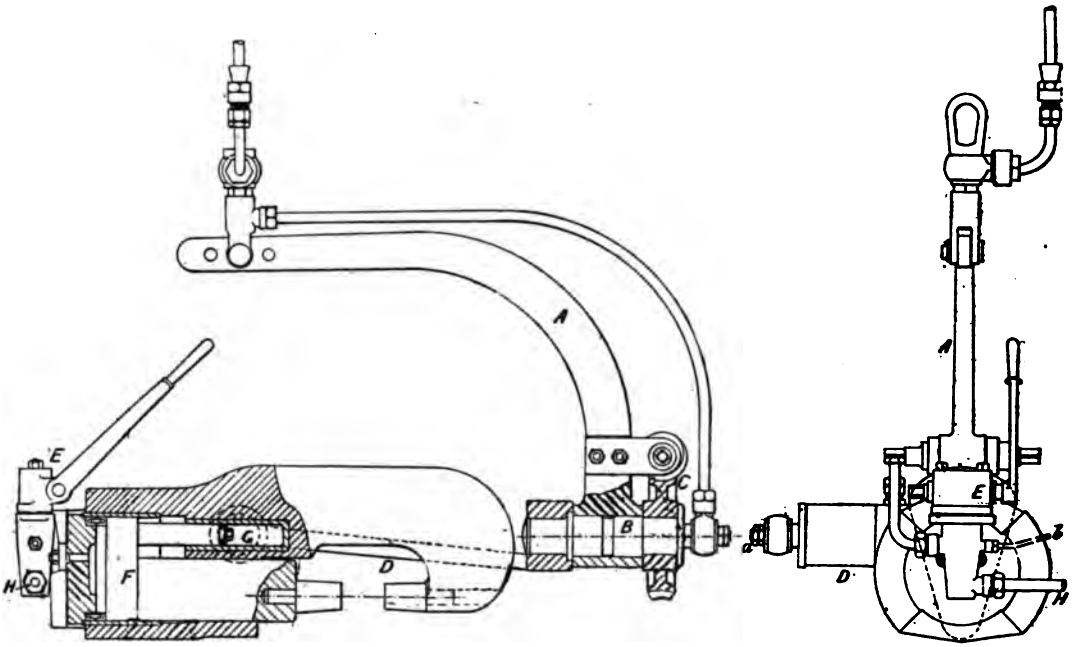


Fig. 224.—Fire-Hole Door Riveting Machine.

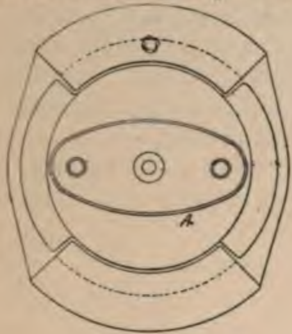
behind C is to cause some of the water behind D to flow back to the accumulator, due to the excess of area of C over that of D. The pressure due to the area of D is still exercised on the cupping tool, until the rivet is secured. The whole pressure can if required be exercised on the cupping ram, by simply throwing the closing ram out of action. J is the returning ram.

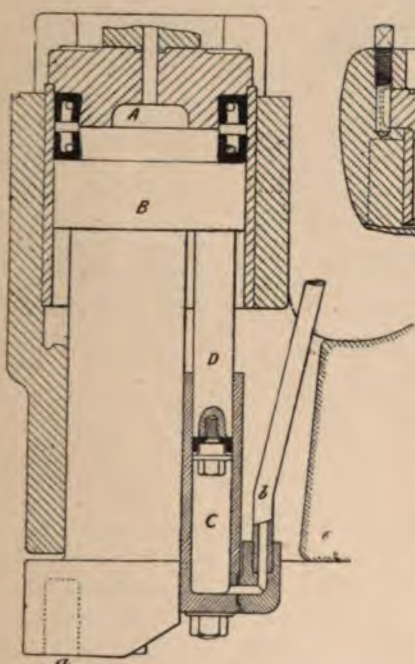
A large machine of fixed pattern is illustrated in Fig. 223, Plate XV. It has a gap of 10 ft. 6 in., the main frames being of Siemens' cast steel, united by bolts. When working from an accumulator pressure of 1,500 lb. per square

Horizontal Riveters.—When riveting tubular objects, as boiler shells and pipes, in the ordinary riveter, a riveting tower is essential, in order to give head room for the work, and room to lift and lower it in. To avoid this is the object of the horizontal riveter. In this the boiler shell is placed on runners on a bogie, and being run to the machine is turned through an arc on the runners, to present successive rivets to the machine. The method is like that often adopted when boiler shells are being drilled under radial drilling machines attached to a wall. The horizontal riveting machine is

carried on a pivot on a floor bracket for ready adjustment for height, and so balanced that one man can move it. Besides this there are horizontal machines for special functions, as for riveting buoys, the ends of steam drums, &c.

Portable Machines.—The portable hydraulic machines are made in numerous designs. They have been developed in response to demands made from time to time for the substitution of machines, for hand riveting, in situations for which previous machines were unsuitable. They are provided either with a plain eye for lifting them about, or with a hanger of simple, or compound type. It is thus possible to present portable riveters to their work in all conceivable positions, and without disconnecting and re-making pipe joints. Many are suspended from cranes and travellers. They are made in a wide range of gaps and powers, with a rigid direct-acting, or a hinged framework, while many are of special designs for doing some particular class of work which standard forms are not able to reach. Two or three selections only from the great variety of forms can be illustrated.





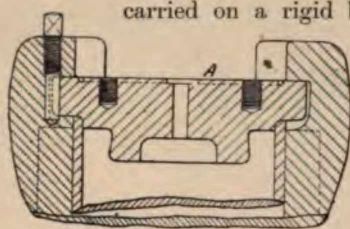


Fig. 226.—Section through Cylinder of Hydraulic Riveter.

Fig. 224 illustrates a 40-ton power fire-hole door riveter, by Messrs Fielding & Platt, Ltd. It is suspended by the bow A, which carries a boss and gudgeon B at its lower end, around which the machine itself can be rotated to all angles by the worm gear C. The machine is carried on a rigid bar D, which terminating in a boss permits the machine to be pivoted at *a*, and to work at an angle. The lever and valve at E regulate the pressure water behind the ram F. G is the drawback cylinder, which works under constant pressure through the pipe *b*; H is the exhaust.

A portable riveter employed for the furnace mouths of marine boilers, when the end plates are flanged outwards to join the shell, is shown in Fig. 225, Plate XV. The riveter is pivoted on a gudgeon as in Fig. 224. The beak is made loose, and of forged steel, in order that it may be shallow enough to work in narrow spaces between the furnaces. The effective gap is 4 in., and the power 40 tons.

A section is given through a standard type of cylinder, Fig. 226, used for the direct-acting machines by Messrs Fielding & Platt, Ltd. It shows a steel casting with a gland shaped cover A through which the water enters from the valve. It fits closely with an hydraulic leather, the cylinder being bushed with gun-metal. The ram B receives the cupping dies at *a*. The drawback cylinder C receives a constant supply of pressure water through the pipe *b*, so returning the ram D as soon as the valve which supplies it is closed.

A bear type of direct-acting riveter by Musgrave Bros. is shown in Fig. 227, Plate XV. The objection to this type is that it cannot be used in corners, but in other situations it is very satisfactory. The main ram is automatically returned by a small ram under constant pressure. The hanger is of the bow type, which permits the machine to be turned about into any position. The gun-metal hook from which the hanger is suspended is hollow, and it forms a medium for the passage of the water to the flexible pipe going down to the gudgeon joint. There is also a hook on the latter, for suspension.

mechanism is shown in Fig. 228. A and B are the two lever arms pivoted at C; D is the cylinder, E the ram, F the valve which controls the water supply to the cylinder. G is the return cylinder and ram. These riveters are made with the common bow, and with compound hangers. They are made in sizes ranging from 15-in. to 60-in. gaps, and with openings from 12 in. to 15 in. wide.

Another method of operating the levers is by a straight ram, pressing against a roller at the end of the opposite lever, Fig. 229, Plate XV. The two levers pivot upon a gudgeon pin, and

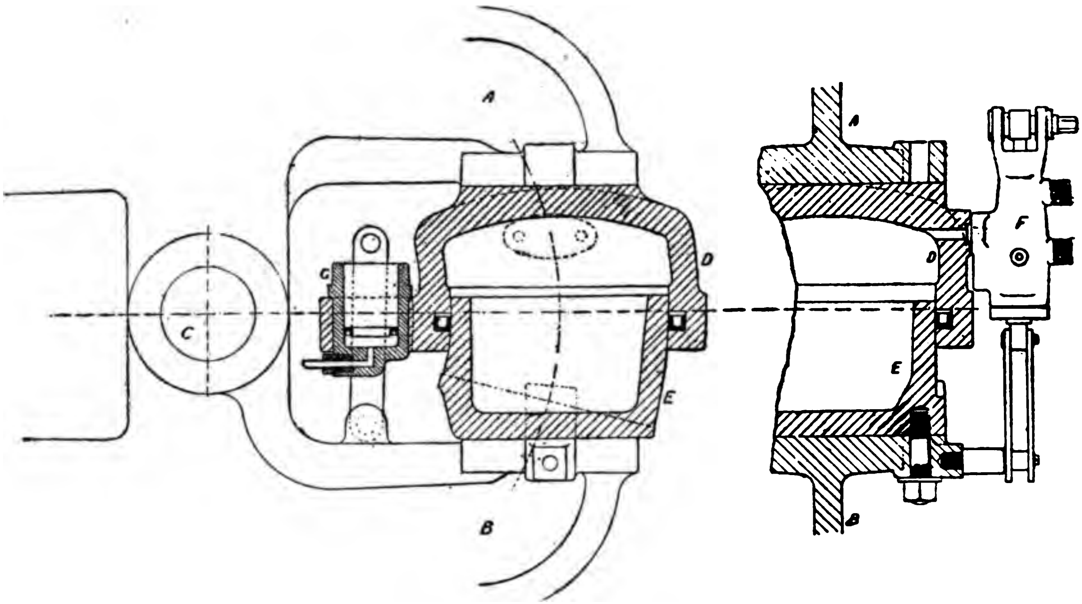


Fig. 228.—Cylinder and Ram Actuating Hinged Riveter.

One of the most valuable of the portable riveters is the Fielding patent, in which the hydraulic cylinder and ram occupy respectively one end of two levers, the other ends of which carry the riveting dies, the levers being hinged midway. The cylinder and ram are curved in the plane of their common axis, and their centre line follows the radial path of the arms. Connecting rods are thus avoided, and the design is perfectly rigid in working. The advantage is that the action of the riveting dies is not interfered with by the obstruction of the cylinder, and that they can therefore be got into corner work otherwise unapproachable. The essential

the whole machine is suspended from a hanger which is provided with worm gear for angling about the axis of the gudgeon pin; there is also a worm gear on the suspension link, which holds the arch of the hanger up by two rollers, the worm turning a pinion engaging in a rack cut on the top of the arch, so that the latter may be moved to right or left to tilt the machine.

An average of from 80 to 100 rivets per hour can be closed in boiler work with a fixed machine. 1,500 rivets per day of ten hours can be put in bridge and girder work with a portable machine.

Pneumatic Riveters.—Compressed air has been used for about twenty years for the opera-

tion of portable riveters. An early form is Allen's. It is a hinged riveter, its levers being pivoted at the centre, and being actuated by the movement of a piston attached near the middle of one lever, and moving the ends opposite the cupping dies through a series of links. The action is such that the pressure exercised is slight at first, but increases gradually, and is at a maximum at the moment of final closing.

pneumatic hammer type of riveter held in the hand, the yoke form of machine is preferable, in which the head of the rivet receives support in opposition to the hammer blows of the snap. Often the yoke cannot be used, as in riveting done over large areas, as ships' decks. Then the support and the hammer must be wholly disconnected. In such cases the deck-riveter, Fig. 230, Plate XV., is useful. The hammer

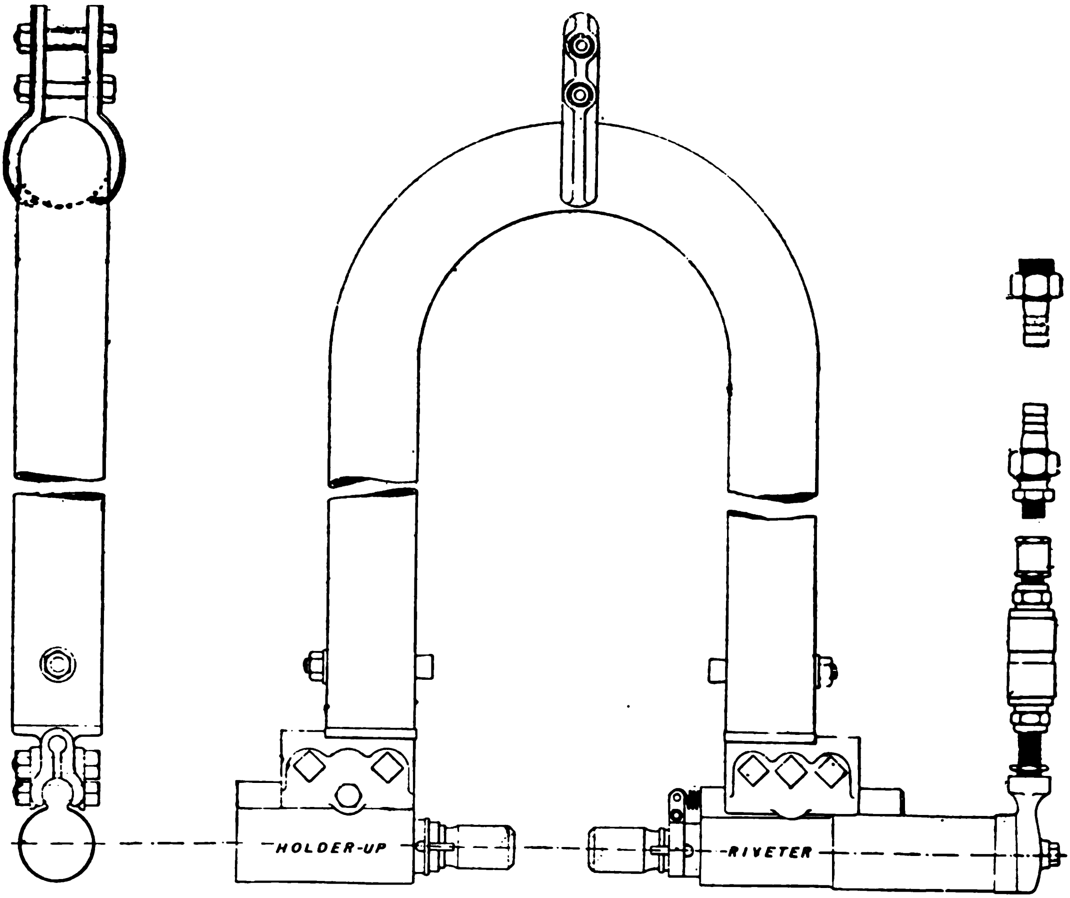


Fig. 231.—Boyer Yoke Riveter.

Pneumatic riveting has advantages over hydraulic by reason of the superior lightness and portability of the machines. There is room for both in a large works. But the fact that compressed air can be used for chipping, caulking, drilling, reamering, &c., is all in favour of the installation of a compressed air plant. Though large rivets can be driven by the simple

is placed inside a shell pivoted on the end of a tube which is connected at the other end to a cross axle carrying two wheels which run upon the deck. Suitable weights are dropped on to the tube near the hammer to keep it down.

The gap-riveters of pneumatic type include also the hammer class, in which, instead of a

steady squeeze, a number of blows are delivered by a mechanism similar to that in the **Pneumatic Riveting Hammer.** The result is that the frame does not have to withstand a great force tending to thrust the arms apart, and consequently a very light construction can be adopted. In Fig. 231, which illustrates the Boyer gap-riveter, made by the Consolidated Pneumatic Tool Co., Ltd., the frame is of tubing, bent into horse-shoe form. Two sizes of machines are made, for rivets up to $1\frac{1}{8}$ in. and $1\frac{1}{2}$ in. diameter respectively, and with a reach in the gap of from 30 in. up to 72 in. The frame has a clip at the top, by which it can be suspended. The riveting head, and the opposing holder-up are held in the ends of the tube by cotter bolts, through intermediary brackets, which permit of adjustments being made by slacking the three clamping bolts in the riveter head, and sliding the latter longitudinally, the holder-up having a similar fitting. The space between the snaps should be about $\frac{5}{8}$ in. more than the length of the rivet to be closed. The stroke of the snap piston is 5 in. in one machine, and 6 in. in the other. The air is admitted, at a pressure of about 100 lb., through the coupling tubes at the end of the riveter head, and is controlled by twisting the handle or sleeve on the pipe, which puts passages into communication similarly to those operated in the **Pneumatic Drills.**

Representative tools used for pneumatic riveting are shown in the article on that subject. Pneumatic riveters of one or another design will do all that can be done by hand riveting, and more, because they will work in confined situations where there is not room for hand work. The cost of pneumatic riveting of $\frac{7}{8}$-in. rivets is 4s. 6d. per hundred, that of hand riveting is 10s. 6d. In America pneumatic riveting is given as 6s. 7d. per hundred, hand riveting as 15s. per hundred. The machine riveting gives better results, there are fewer loose rivets, and the heads are perfect.

Hand v. *Machine Riveting.*—Hand-closed rivets can often be distinguished from those which are machine closed by their better finish. The snap in hand riveting makes a neat annulus, and clean edges around the rivet, while in rivets machine closed there is usually a sensible thickness left around the rivet edge. The work is none the worse for that, and in most cases it is certain that machine riveting is more efficiently done, especially in steel rivets, many of which when closed by hand become cracked by the finishing work done upon them while at the blue or black heat. When closed by machine they are finished while yet red hot. Professor Kennedy's experiments on riveted joints did not show that machine riveting imparted a higher ultimate strength to a riveted joint than good hand riveting. But they proved conclusively that machine riveting makes tighter joints, so that slipping in the latter case does not begin until about twice the load is reached which produces slip in a hand riveted joint.

Rivets should never be too long for the plates which they have to go through. If they are too long, and closed with a power riveter, something will have to yield, and it may probably be the plate between rivet holes. Closing by hand will not produce this effect, the only difference being that the closed tail when snapped will be standing higher than as though the rivet were of the correct length.

That a rivet should well fill up its hole is of more importance than that the tail should be neatly turned over and finished. This point is in favour of machine riveting, because the full pressure is transmitted through the mass of the rivet, squeezing it until it fills up its hole. In much hand riveting the blows delivered upon the tail are so light that the snap is simply turned over and formed without any appreciable pressure being transmitted through the body of the rivet. The larger the rivet the more marked is the difference in this respect between machine and hand riveting. The object sought should be to shorten and expand the rivet shank by endlong blows, before turning over and snapping the tail. If the tail is beaten over first without regard to the shortening of the shank, the latter will not fill up the hole quite closely, and the risk of leakage or weeping is incurred. In machine riveting the closing pressure is directly endlong, effecting the shortening and expansion of the shank first, and the snapping of the tail afterwards. The thicker the plates, or the greater their number, the greater is the advantage to be derived from

machine riveting. It is as easy to make a long rivet fill up its hole as a short one by machine, but it is not so easy to do so by hand riveting.

Fig. 232 gives illustrations taken through

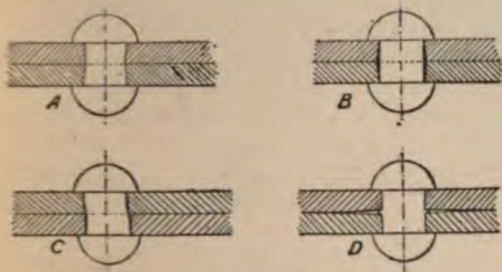


Fig. 232.—Examples of Riveting.

riveted joints. A is the proper way to make a joint in which the holes have been punched. It will be noted that the larger diameters of the holes face outwards and give the rivet an opportunity to fill the holes properly, and assist in pulling the plates together. B shows how the plates should not be placed. C shows holes which are not fair, and that should be reamered out before the insertion of the rivet. D illustrates what happens when the plates are not closed properly at the time of riveting, the effect being termed *washering*.

Riveting Tower.—A tall shaft built at one side or end of a boiler shop to receive Cornish and Lancashire boilers slung vertically for the purpose of riveting up the rings and their seams. It is served by a crane and has a fixed riveting machine in the base.

Rivet Machine.—*See* **Heading Machine.**

Rivets.—The standard forms of rivets are shown in the group, Fig. 233. The usual proportions are given in terms of the diameter *d*. The first in Fig. 233 is the *cup*, or spherical head, the tail being of the same form; the next has a *pan* head, the tail being still spherical. The third is the *conical* or *snap* head, which is a frequent form. It is used especially in furnaces, and cross tubes, on the water side. It is also a favourite shape when light hand riveting is done, especially in sheets and in coppersmiths' work. It can be finished by the hand hammer without a snap, while the cup form has to be first beaten over by hand and then neatly finished by a few blows delivered by a sledge on a snap. The fourth is a rather unusual form, having a head of *ellipsoidal* section, and a tail of conoidal form. It is supposed to be a compromise between the spherical and pan heads, and the spherical and conical tails. The *countersunk* form which follows is used when flush faces are required on one side, the last example when both faces must be flush or nearly so. It is seldom that both faces are required flush.

For forming the rivet tail the allowance in length should be: for a conical tail, diameter of shank × 1·25; for a cupped tail, diameter of shank × 1·5, to 1·75; for machine riveting, diameter of shank × 1·65.

It is generally held that there is no advantage but the contrary in making a rivet head or tail

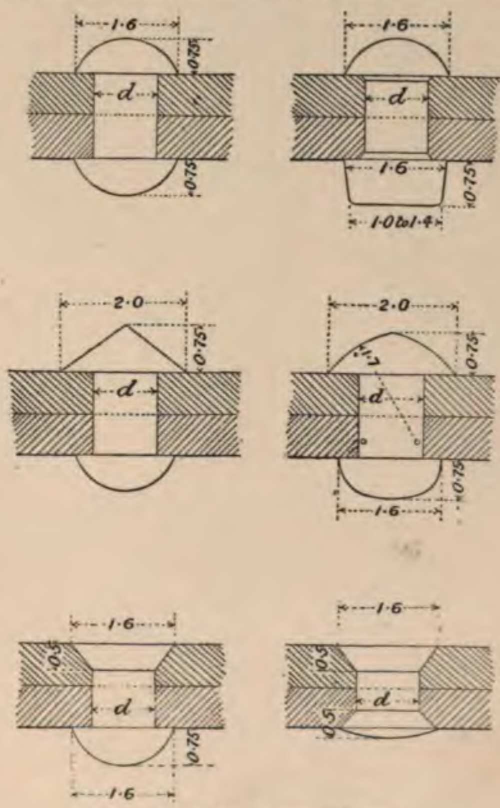


Fig. 233.—Proportions of Rivets.

unusually large, but that the smaller head and tail will hold more tightly than the larger. Professor Kennedy, however, in his researches on riveted joints for the Institution of Mechanical Engineers, found that increasing the weight of

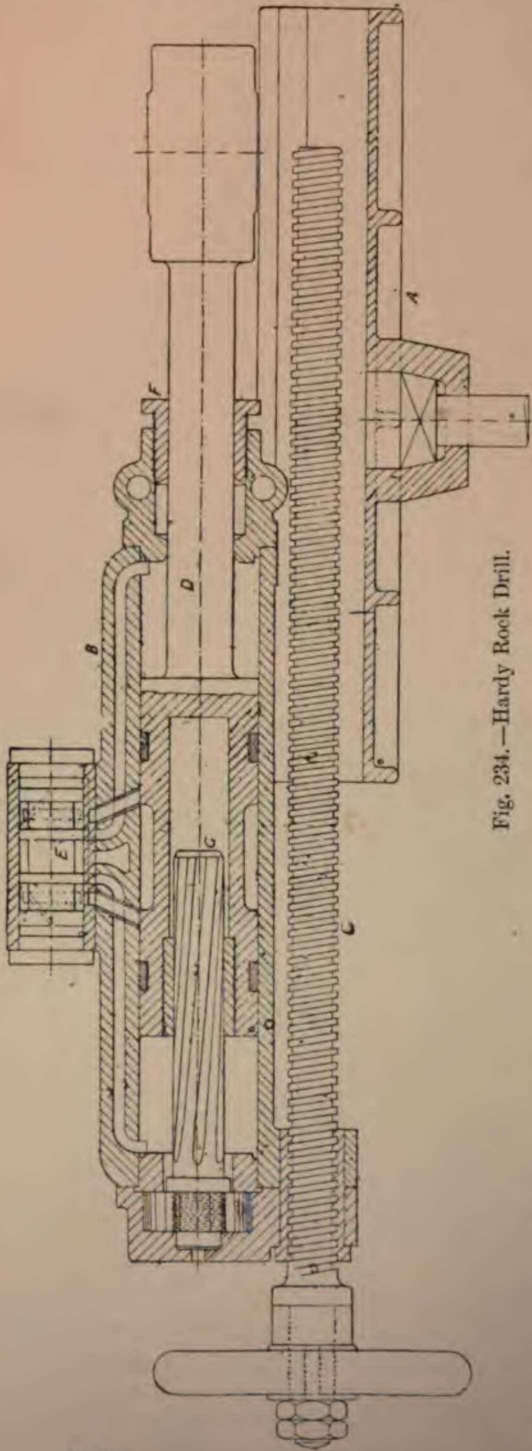


Fig. 234.—Hardy Rock Drill.

the heads and tails of rivets had a marked effect in increasing the strength of a joint. An addition of about one-third to the weight of the rivet, all of course going into the head and tail, added about 8½ per cent. to the resistance of the joint. ¾-in. iron plates, which with the lighter rivets tore through at a shearing stress of 20 tons per square inch, remained unbroken with the heavier rivets at a shearing stress of 22 tons per square inch, at which the rivets gave way.

Road Sand.—The scrapings of flinty roads are used in some districts in the preparation of moulding sands.

Roasting.—*See* **Calcining.**

Robert Converter.—*See* **Bessemer Converter.**

Rock Drills.—Percussive tools employed for boring holes in rock, &c., for blasting charges, wedging, &c. The tool is driven against the rock a great number of times in a minute, and at each stroke is partially rotated, so as to produce a circular hole. Compressed air, steam, and electricity are employed as agents for operating drills; in the two first-named, the to-and-fro motion is effected by a piston or plunger sliding within a cylinder, and driven in alternate directions by the pressure being let on either side alternately; the entry of the steam or air is controlled by a circular valve, operated by tappets struck by the piston, or by the action of the air or steam itself; the latter being the most effective type. The cylinder is carried in a cradle, along the slide-ways of which it can be fed by a feed-screw and handle; the cradle is fixed in a suitable holder, comprising either a tripod, or a vertical or horizontal pillar; when work is done in tunnels the tripod can be dispensed with, and a tunnel column employed, consisting of a stiff bar, which is securely fixed by forcing a couple of screws on the foot against an opposing surface, while the other end takes a bearing against an opposite wall.

Fig. 234 is a section through the "Little Hardy" drill, made by the Hardy Patent Pick Co., Ltd. The shell, or cradle, A carries the cylinder B, fed b[y]
screw C. The piston
two split rings to m
and it is prolonged

F into an enlarged head which receives the end of the drill, holding the latter by a bolt and nut. The valve E controls the admission to each end of the piston; air first gets to the rear end of the piston, driving it forwards; and the exhaust, rushing out in front, goes up the long passage to the right, and throws the valve over, thus admitting live air to the front, and exhausting at the back. With a 3-in. machine, of 6-in. stroke, a speed of from 600 to 650 strokes per minute is attained, using air at 60 lb. pressure. At 40 lb. per sq. in., 400 to 500 blows per minute can be struck. The rotating device in Fig. 234 comprises a spirally-fluted rod, G, fitting in a nut in D, and held at its end in a ratchet wheel, which in conjunction with spring pawls within the end of B cause G to remain stationary when D is moving backwards, so giving D a partial turn.

The Hardy machine on a shaft bar or single-screw column is shown in Fig. 235, Plate XVI. A hinged bracket encircles the column, and this carries a projecting arm on which the cradle is held through an intermediate sleeve, moved around the arm by worm gear. A universal adjustment is thus obtained. Two screws are often used on the foot, the term double-screw column or shaft bar being then applied. Stoping bars are made with a single screw. A quarry bar is a horizontal one supported on four legs, carrying the drill, which can be slid along to drill a number of holes in line. A transverse motion of the entire machine is given after the row has been drilled, to make another row parallel thereto. The quarry bar is used in stone quarries for getting out dimension stone.

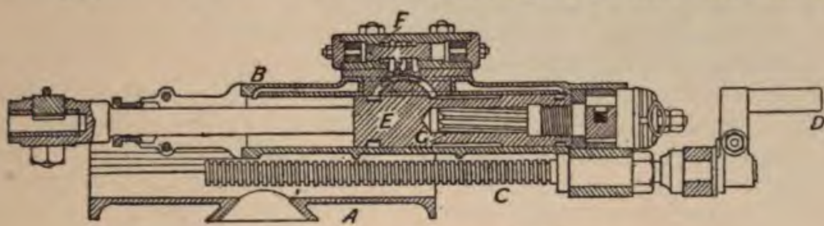


Fig. 237.—Ingersoll-Sergeant Rock Drill.

Fig. 236, Plate XVI., represents the Hardy machine on a tripod, and in operation, drilling vertically.

The Sergeant drill, Fig. 237, has an auxiliary valve motion as seen. The parts lettered are: the shell A, cylinder B, feed-screw C, crank D, piston E, main valve F, and rotation G. A valve plate lying between the cylinder and the main valve chest has an extension fitting into a recess in the cylinder; an arc-shaped groove is cut in which a light valve of curved form

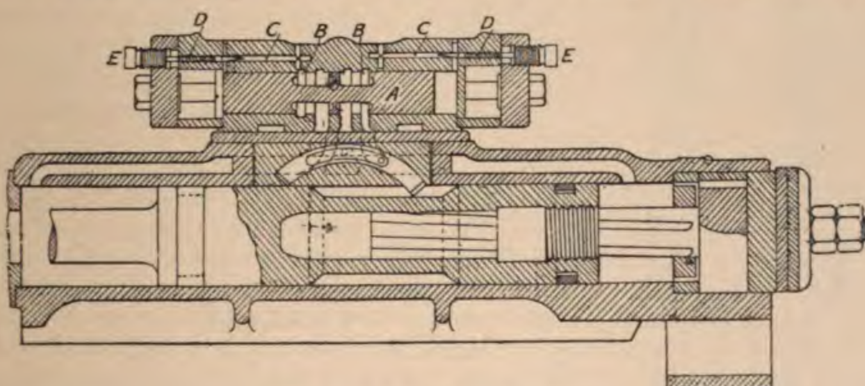


Fig. 238.—Ingersoll Valve Chest.

slides easily. The length of the valve is such that one end or the other must project into the cylinder, so that as the piston E moves along it strikes the valve and throws it up a very little, and has the effect of opening a small port, which releases the pressure from one end of the valve F. The full pressure on the opposite end of F drives it back, and lets in the pressure to the piston for the return stroke. The positive action of a tappet mechanism is thus secured, without the corresponding disadvantages incurred in some of the older tappet drills, while the variable stroke of the main valve is retained. A new form of valve chest, shown in Fig. 238, is applied to the Sergeant drills with the object of compensating for wear on the valve, which is liable to impair the proper action. The valve is marked A, and the supply ports B, B. Small ports or by-passes C, C connect B, B with the ends of the valve chest, through transverse holes; setting screws D, D, adjusted by turning squared necks, provide for altering the amount of opening, so that as air leaks past A, due to its wear, the regulating screws D, D may be turned in further, restricting the leakage through the ports C, C, and so restoring equilibrium to A. The screws E, E merely serve to lock, and protect D, D.

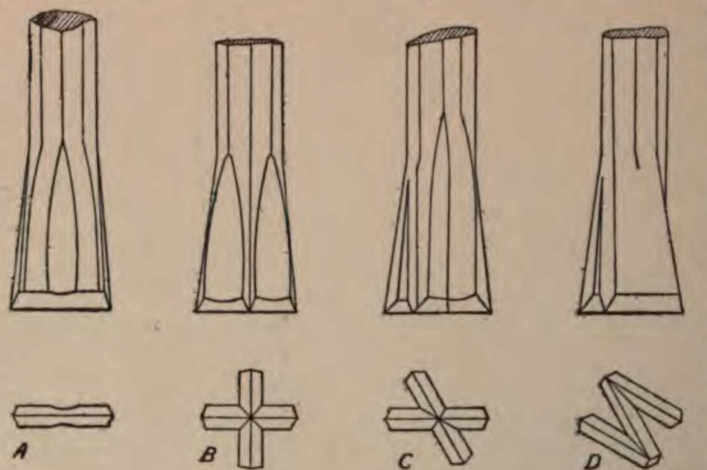


Fig. 239.—Rock Drills.

Four of the most common types of drill points are shown in Fig. 239. A, the chisel-shape, is suitable for homogeneous rocks free from faults; it cuts rapidly, and is easily sharpened. But in rocks which are composed of uneven layers, with fissures, this bit is liable to stick, to get out of line, and so give trouble. The cross-bits B, and C are therefore used for such ground. Soft rocks can sometimes be advantageously worked by the Z-bit, D. The last three ends are more difficult to trim and sharpen than the first. The cross shape B is on the whole used more than the others.

Electricity is a rival to steam and compressed air for the operation of rock drills. Fig. 240 shows one method of producing the reciprocating motion, in the Sandycroft-Marvin machine. Here a plunger, A, provided with a tool socket, a, is guided through a bearing, b, at the end, and slides in a steel tube surrounded by solenoids, B and C. The solenoids are composed of square section copper wire wound over mica sleeves, with a steel jacket outside of all. Current is brought to the coils through terminals at D, and by employing an alternating current of low frequency, the magnetic effort induced in each solenoid is varied from maximum to minimum alternately, so that the plunger A is drawn to and fro rapidly, making 385 impulses per minute. The return stroke of the plunger is received by a strong helicoidal spring, E, which also helps it forward on the out-stroke. The partial rotation of the drill is effected by a rifled ratchet rod, F, in conjunction with a ratchet wheel, G; F fits a nut in the end of A. The feed-screw H is turned by the handle J. A special design of generator is used to produce the required current for the drill, through slip rings and commutators, which have the effect of forming a wave with a flat top, lasting over half a revolution.

Fig. 241, Pl
mounted upon
The jointin
drill to
horizon

leg, and keep the machine down against the resistance of the cutting.

Rocking Grate Bars.—*See* **Mechanical Stokers.**

Rock Sand.—Abraded rock used in sand mixtures for cores.

Rock-Shaft, or **Rocking Shaft.**—The weigh-shaft, weigh-bar, or reversing shaft of reversing valve gears. *See* **Link Motions.**

Rod Chisel.—The smith's sett or chisel held by reins or handles of withy or iron, so termed to distinguish it from the anvil chisel.

Rodding.—Laying short lengths of iron rod in moulds to support the sand over weak sections.

Rod Mill.—A rolling mill employed for producing rods for wire. The principal type is described under **Looping Mill.**

Rods.—The round sections of $\frac{3}{8}$ in. or less diameter rolled specially to be drawn into wire.

Rolled Beams.—*See* **Joist.**

Roller Bearings.—The substitution of rolling for sliding friction is the design embodied in these bearings. The difference between these and ball bearings is only that of *line* and *point* contact, rolling being the principle embodied in both. But experience proves that the rolling of cylinders is better than that of balls for heavy axles, journals, and shafting, the rollers being more durable. The advantages over sliding friction are so obvious that the roller design has largely taken the place of the latter in classes of work where the reduction of friction is imperative, and where the extra cost can be incurred. A roller will run down an incline of 1 in 100, while a block of polished metal will not run down a well-oiled metallic surface with a slope of less than 1 in 14. Since the introduction of these bearings a good many designs have been offered. They may be divided very broadly into the flexible types, represented by the Hyatt, and the solid, which includes all other types. The difference is that in the first-named the rollers are each formed by winding a strip of tough steel of rectangular section into a helix. The helix lies in close contact, and forms the cylinder. The advantage claimed over solid rollers is their flexibility, by virtue of which they will accommodate themselves to inequalities in shafts from want of exact truth, or of exact alignment. The rollers are confined in their boxes either by means of yoke guides, or of pins passing through the centre. In these details the rollers of different makes vary widely.

It is seldom that rollers are allowed to run loosely in their cages or races. It is usual chiefly in the conical form of rollers used in the live rings of turntables. In

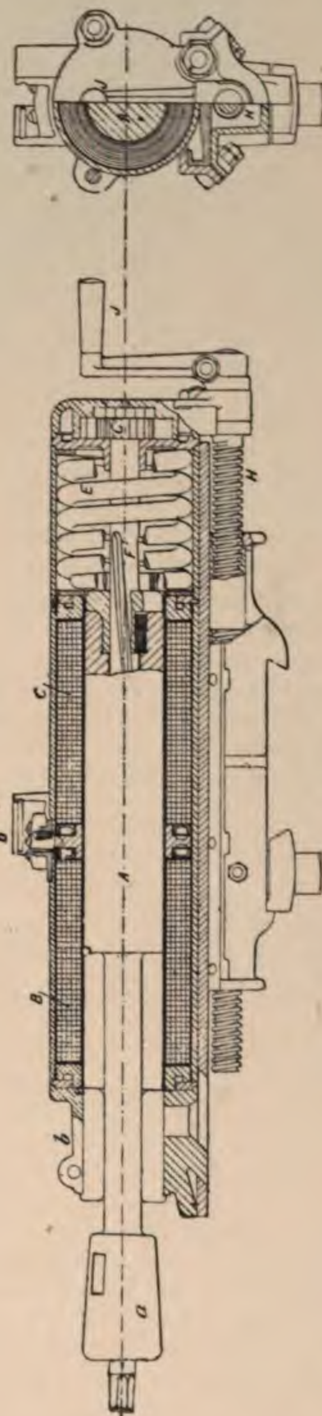


Fig. 240.—Electric Rock Drill.

ordinary parallel roller bearings the friction set up by the contact of adjacent rollers would be undesirable. Hence they are kept apart by *cages*. In some cases the rollers are located in small sets, as three in contact, but separated from other sets by strips in the cages, as in the yoke guides

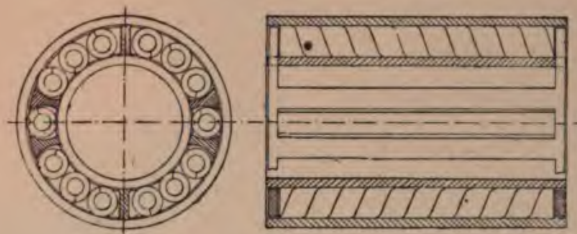


Fig. 242.—Hyatt Bearing.

of the Hyatt type, Fig. 242. Fig. 243 illustrates a Hyatt bearing fitted in a plummer block.

But in the majority of instances, perhaps, each roll is carried on its own rod or pin, a series of which run along the cage connecting the circular end rings. In another design the main rollers are separated by other smaller rollers, and in others the end rings are recessed to receive the ends of the rollers. The ends are united by bars between the recesses. Some firms fit a ball at each end of each roller to reduce its friction.

In some conical roller races a similar design is adopted, a ball being fitted centrally in a recess in the larger end of the roller, and thrusting against a pin screwed in the outer ring, the endlong pressure of such rollers being only outwards.

The rollers sustain all the friction of revolution. They run between an outer casing or bearing and an inner sleeve which fits the shaft or axle journal closely, and the outer surface of which forms the inner path for the rollers. Usually, in solid rollers, all parts in rolling contact are hardened, and this combined with the rolling action has yielded remarkable results.

Roller Path.—When a massive structure, as a crane, swing bridge, or a turntable, has to rotate around a central pivot, the strain on the pivot is relieved, and steadiness of movement secured by supporting the revolving mass on rollers arranged in a circle of large radius. In some cases a belt is turned round the pivot, and the rollers run round this belt with their axes of rotation vertical. This method is adopted in many of the smaller cranes. In other cases the rollers run round a path turned at an angle of about 45° on the edge of the slewing ring, the axes of the rollers being set at a corresponding angle. Often the rollers are so arranged at front and back, but the side rollers run round a belt on the post as before. But in all large cranes and turntables the axes of the rollers lie in a horizontal plane, and they run between paths the faces of which, with the edges of the

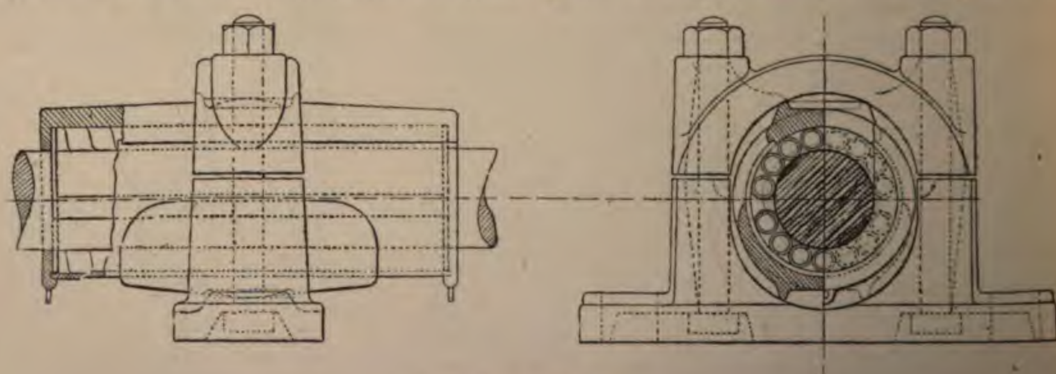


Fig. 243.—Hyatt Bearing.

rollers, make conic frustra, with the centre of revolution of the crane for the apex. In some cases the upper roller path is or [illegible] rollers then run on a lower [illegible] bearings in a circula[illegible] *live rollers* is [illegible] run [illegible]

ve roller arrangement each roller may own radial rod, but that is not usual. ugh if about every fourth roller is so d to the centre piece. The intermediate on pins which are bolted through the girders which carry the entire set of

ollers are usually cast, being amply ough in cast iron or steel because they a well distributed load. The frames of channel section. The rollers are is are also the paths.

rs.—Rollers are employed in agri-

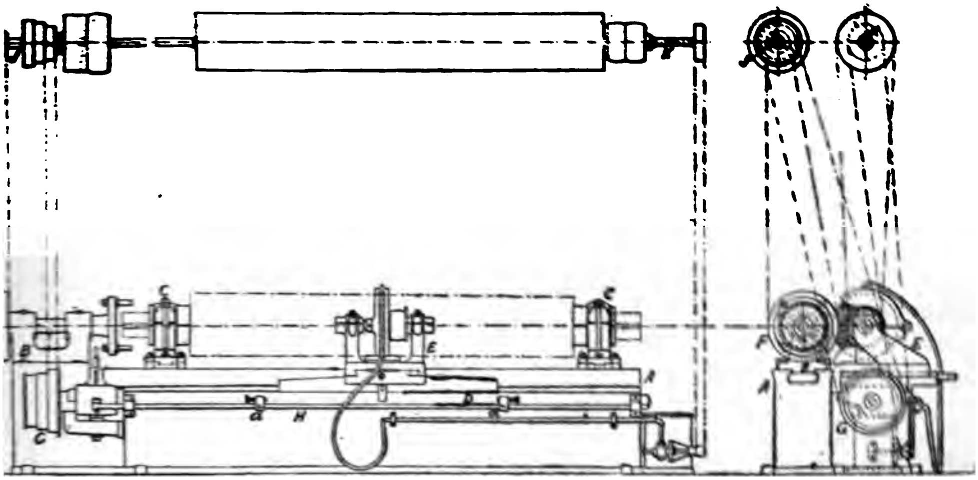


Fig. 244.—Roll Grinding Machine.

o go over the land and consolidate it; l form is that of an iron roller made in ions, to permit of easy turning, and on an axle fitted in bearings at each nected to a shaft or a pole to which the are yoked. In some cases a number of sectional rollers are strung side by side to the required width, the advantage at the turning is done more easily and disturbance of the soil. Fluted rollers, l of many wheels having wedge-shaped used also; the soil is pressed around the the crops, or the seeds, and so favours and checks weeds. Clod crushers are type of roller, constructed with a of serrated discs or rings which break rush the clods of earth.

Grinding Machines.—These are designed to do the work of plain roll turning, with greater expedition. One of these, by Mayer & Schmidt, is shown by Fig. 244. There are two beds, one A, on which the headstock B is bolted, and the divided bearings C, C, in which the roll is carried; the other which receives the carriage E of the grinding wheel which is traversed along past the work. The roll is revolved by a three-stepped cone pulley F actuating a double driver. A three-stepped cone G traverses the wheel by means of a long screw within the bed. A reversing rod H, with adjustable dogs a, a, changes the direction of traverse. There are two countershafts, one J, driving the work and the feed cones; the other K, the long drum, and the pump pulley.

Rolling Circle, or **Generating Circle.**—*See* **Gears.**

Rolling Friction.—*See* **Ball Bearings, Roller Bearings.**

Rolling Load, or **Moving Load.**—A load such as that of a locomotive and train passing over a bridge. It is a live load intensified by certain concentrations of loads in different positions which stress the members of the structure in a dangerous manner, between extremes of maxima and minima. It is usual to assume that all the weight of engines is concentrated on their driving wheels. The stresses due to this have to be calculated for all the members, and added to the stresses due to the weight of the trusses.

Rolling Mill.—This term signifies the actual mill used in reducing piles, ingots, blooms, or billets to sectional shapes; or it denotes the entire arrangements of the shop; the forge, or mill, in which the operations of rolling, and those which are allied and essential thereto are performed.

The Forge.—It is usual to apply this term to the rolling mill in which puddled bars, blooms, and slabs are prepared from the puddled ball. It includes the squeezers, hammers, and forge train, or puddle rolls. The term mill is usually applied to the department in which the blooms or slabs are rolled into merchant bars, plates, and sections. No such distinction is made in steel work. In fact the essential difference in the piling and welding of iron in small quantities, and the fusion of steel in large masses, results in radical differences in the lay-out of the mills. In iron making the puddling and reheating furnaces are grouped in proximity to the squeezers, hammers, and rolls. In steel making the furnaces are not situated in the same department as the rolling mills. The masses handled being so much heavier, the area of the shops is larger, and the machinery more powerful, besides which the plant has characteristic features of its own. With the exception of the actual rolls there is little resemblance between the plant used in the manufacture of iron and of steel. The difference between handling piles of from 3 to 5 cwt., and ingots of as many tons, affects everything—furnaces, the size of the rolls, cranes, and auxiliary plant and machinery.

The Rolling Mill.—The actual mills for rolling sectional forms include several types. They are the *two-high mill*, the original form, also termed the *pull-over mill*, because the bars or plates have to be lifted and pulled over the top roll after each pass. This is becoming obsolete, except for some special kinds of work. The *two-high reversing mill*, in which the direction of rotation of the rolls is reversed after each pass, in order to avoid the lifting and pulling over. This represents the type which is used more than any other for ordinary heavy work. The *three-high mill*, in which reversal and the pull over are avoided, by passing the bar through between the lower and middle roll for one pass, and back between the middle and upper roll in the succeeding pass. This is used extensively, but to a much greater extent in America than in Britain. These are the types of mills ordinarily used for bars, plates, and sections. Two more special types are the *looping*, or Belgian mill, and the *continuous mill*. The first named comprises several stands of three-high rolls arranged end to end, and the wire or rod is looped round and turned back after leaving one roll, into its successor, and so on. The continuous mill is a two-high mill having the stands of rolls arranged one in advance of the other, so that the bar is passing through them all at one time. The idea was to avoid the pull over. It is not used for the purpose for which it was originally designed, that of rolling rails, but has been largely developed for wire rods, and the light sections of merchant iron.

In steel mills, live rollers are essential on account of the weight of ingots and slabs. They comprise a series of rolls of from 14 in. to 24 in. in diameter, driven in unison by mitre gears, one pair to each roll, from a shaft driven by an engine, or electric motor. The rolls are of cast steel, or iron, level with the floor or raised above it, and having foot plates between for the men to stand on.

When three-high mills are used, tables have to be fitted to lift the ingot or plate from the lower to the upper pass. *Tilters* are used for turning pieces over when they have to be so handled between successive passes. These are used for ingots and slabs. *Skids* or travelling tables are required when bars and sections have to be transferred laterally from roughing to finishing rolls. The *hot bed* is a large area occupied by bars or rails, on which the bars or sections are placed by skids and left to cool.

Rolling Mill Engines.—Engines used for driving the rolling mills in iron and steel works. They include several types; high pressure, either non-condensing or condensing, and generally horizontal, either reversing, or non-reversing.

Most engines are of reversing type. These were introduced by Mr Ramsbottom of Crewe in order to avoid the labour of lifting and pulling plates over the top of the non-reversing mills used up

n failure was predicted, because it was ary to abandon the flywheel with its ous momentum if reversing was to be sed, and until then all mill engines used eels, the momentum of which was cond essential to prevent the mill from being ed" or pulled up when a bar was first d between the rolls. But the flywheel was ssential in the days of low steam pressures, ow piston speeds, and heavy reciprocating It was generally put on a second shaft l up from the crankshaft, done in order a flywheel of moderate dimensions. In resent engines the crankshaft is coupled ly to the rolls.

rizontal reversing mill engines are frely of compound type, often also with nsers. Two cylinders are most frequent, iere are examples of three-cylinder engines are ready to start in any position of the pins. The engines are geared down to lls in the proportion of $2\frac{1}{2}$ or 3 to 1. eversal is effected by the engine driver, everses the slot link motion of the valves ans of a small steam cylinder. *See also* **rsing Rolling Mills.**

lls, Roll Turning.—Relates to the rolls, and grooved, which are used for the ction of plates, bars, rods, and the numerctional forms of iron and steel used in uctional work. Until about the middle seventeenth century all shapes in wrought whether plates or bars, were produced by ammer. Grooved rolls were patented by n 1783. But he spoke of them as being well known, and his patent did not cover separate use, but only in connection with goting or piling of iron and the welding haping of iron in rolls instead of by ers. But the general substitution of rollor hammering dates from this period. reat value of the process has been partibscured by the other invention of Cort, f puddling. For an account of the rolllls before Cort, see a valuable article by . Durfee in *Cassier's Magazine*, April

rolls used are either cast iron, cast steel, ged steel. Cast iron is the material most lly employed. Special mixtures are made tough and durable, and are cast vertically in moulds of dried sand, or loam. These are used for the work of reduction. But for finishing, when a smooth polished surface is required, chilled rolls are used. These are also of cast iron, but the working surface is poured against a cylinder of cast iron, bored smoothly. These are termed *chilled* rolls to distinguish them from those cast in sand, which are *grain* rolls. A good deal of skill and experience are essential to the production of sound chilled rolls, free from tension; and the expense of the chills, and their tendency to crack and rapid wear nearly double the cost of the chilled, by comparison with grain rolls. Certain chemical compositions are desirable in order to obtain sufficient depth, and hardness of chill. *See* **Chilling**.

Cast-steel rolls are now used for cogging mills, as being stronger than cast iron. Steel, however, does not chill, and is thus not suitable for taking the place of chilled cast-iron rolls. Forged steel is often employed for the larger sizes of plate rolls. The advantage is that the diameter can be kept down, and the weight and dimensions of the rolling mill thereby lessened. Rolls which are long in proportion to diameter would break in cast iron, while in forged steel they would spring, the effect of which can be counteracted. Some grooved rolls are also made in steel, as when there are keen edges which would receive damage in cast iron. Steel rolls must be of special composition, ordinary mild steel would be too soft, and therefore hardening alloys must be introduced.

Rolls for plates have to be turned rather smaller about the central parts than at the ends, because they expand by the heat of rolling. Long rolls also spring. *See* **Plate Mill.** Rolls for sectional forms give no trouble in this respect. The difficulties in these lie in imparting the correct amount of draught to the successive passes, the choice of the best methods for the suppression of fin, and the provisions necessary for doing sufficient work upon the metal without distressing it over much. The deeper the grooves the greater the difficulties, the most awkward shapes being channel, and joist sections. *See* **Channel Rolls**, and **Joist.** The amount of taper is determined by the depth of the grooves, being increased with depth.

Hence when possible, as in angle sections, these are rolled with both webs placed at about equal angles, so lessening the amount of tearing or scraping action which goes on in nearly perpendicular faces. The smaller the diameter of the rolls the greater the difference in the surface speeds at the periphery and nearer the centre. Hence large rolls are preferable to small ones, but they cost more, and take more power to drive. There must therefore be a balancing of conditions in their design. The roll sections are determined by the forms to be rolled, hence the distinction between *open*, and *closed* passes. In the first there is an open space between the rolls into which fin is squeezed, but which is obliterated by turning the bar round in the succeeding pass, as in rolling rounds and squares. But in angles, channel, joist, and allied sections which cannot be turned about, the passes are closed by collars turned on the lower rolls, and extending above, and enclosing the section, so that no fin is permitted to form.

The upper roll is always made rather larger in diameter than the lower, in order to slightly stretch the upper surface of the plate, bar, or section, and so cause it to curve downwards towards the floor. The difference is slight, ranging from about ¼ in. to 1 in., increasing with the diameter, and with deep sections.

The amount of reduction, or *draught* at each pass varies extremely. Speaking generally, it is made as large in amount as possible in order to expedite the work. The amount of reduction may vary from 20 per cent. in roughing to 15 or 10 per cent. in finishing. It varies with temperature, since in the early passes a greater reduction can be made than in the later when the bar is cooler. It varies also according to whether the webs are nearly of the same section, or greatly different, since the thinner portions must control the amount of reduction. The speed of rolls varies in different cases from 30 up to 600 revolutions per minute, the slower speeds being for cogging, and for plates, the higher for the rod mills. The tendency is to increase speeds.

Roll Turning.—This is the work of a man who is responsible for the results of the rolling. He designs the shapes of the grooves and the amount of draught of the successive passes. The successive passes are marked on a construction line, which passes very approximately through the centre of gravity of the sections. Experience alone becomes the guide to the draughts, and the tapers, and the provision for removing fins.

The lathe used is of dead centre type, in which the roll is rotated by gears, either between the dead centres, or with the necks in bearings

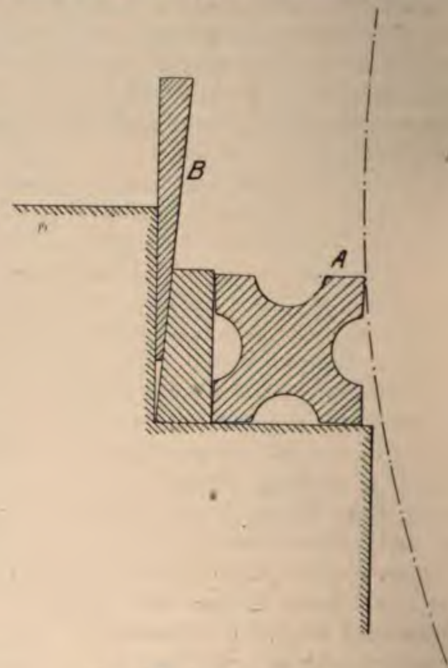


Fig. 248.—Roll Turning Tool.

rigged up on the bed. Fig. 245, Plate XVI., illustrates a 22½-in. lathe driven through belt pulleys and gearing. It has one set of neck rests, with rest bar for turning plain chilled or grain rolls, and also a necking rest, adjacent to the loose headstock.

A 12-in. centre lathe, driven through a step cone, is shown in Fig. 246, Plate XVI. The cone has three steps, and this in conjunction with two pairs of change gears gives six speeds to the spindle, which is revolved by worm and worm wheel, provided with an oil bath. Two sets of neck rests are shown, each with piano tool-rest, tool-holders, setting-up screws, and carrier bars for supporting the top roll when turning the bottom one to match. The lathe

Fig. 235.—Rock Drill on Column.

Fig. 236.—Rock Drill on Tripod.

(The Hardy Patent Pick Co., Ltd.)

Fig. 241.—Electric Rock Drill on Tripod.
(The Sandycroft Foundry Co., Ltd.)

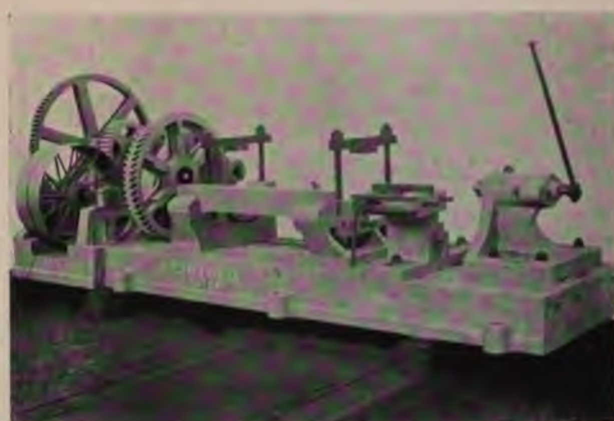


Fig. 245.—Belt-Driven Roll Turning Lathe.
(Thos. Perry & Sons, Ltd.)

Fig. 246.—Belt-Driven Roll Turning Lathe.

Fig. 247.—Electrically-Driven Roll Turning Lathe.

(Thos. Perry & Sons, Ltd.)

To face page 234.

is particularly suitable for turning grooved rolls, though plain ones can, of course, be turned as well.

An electrically-driven lathe, of 26-in. centres, is shown in back view, Fig. 247, Plate XVI. The motor is of variable speed, 3 to 1, and drives through raw-hide pinion and steel gearing to the spindle. There are two pairs of change wheels, which are thrown in or out of gear by means of the handle seen just in front of the large spur gear.

Chilled rolls are turned with a tool, A, Fig. 248, having squared edges with concave faces, so that the action is that of scraping. The tool does not traverse, but is simply fed in by driving wedges, B, behind it, after which it is moved along to a section adjacent. Grooved rolls are turned to templets of the sectional shape required, and the tools are shaped to match the templets.

Roofs.—The timber framed roof has been largely displaced by the roof of similar design in iron and steel, built of bars and angle sections, combining adequate strength with lightness of structure, and little obstruction of daylight, or harbourage of dust.

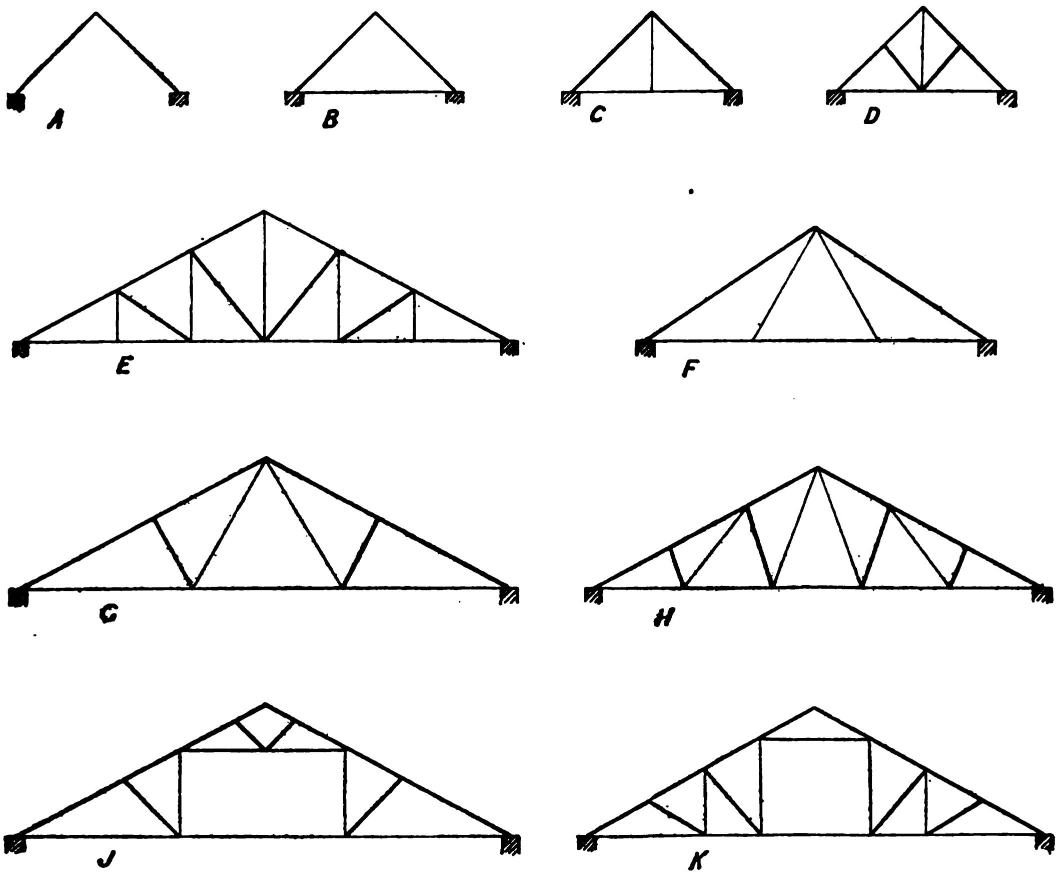


Fig. 249.—Roofs.

The first principle embodied in a trussed roof is that it is self-contained, that is, it is independent of any outside support, so that it exercises no outward thrust on the supporting walls or columns. The methods of calculation for different types of roof may be studied in works devoted to the subjects of stresses in framed structures. The simple and essential

elements are the inclined rafters, Fig. 249, A, the outward spread of which is prevented by the fitting of the tie-beam, B, which forms the base of the triangle, and which in its turn is supported at the centre by the king-post, C, connecting the tie-beam to the apex of the rafters. It is important to note that the load of the roof is taken by the inclined rafters, which are therefore both in compression. This will be compounded of a downward thrust,—compressive,—which is taken by the wall, and a horizontal thrust which is taken by the tie-beam,—tensile,—equal to the thrust on one side of the truss. The king-post is in tension, but it only has to support the sag of the tie-beam or tie-rod, and nothing due to the roof rafters. As spans increase in width,

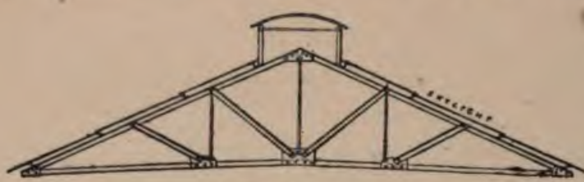


Fig. 250.—Roofs.

diagonal struts are fitted, D, extending from the base of the king-post to the rafters, and affording support to the latter somewhere between their apex and their point of attachment to the tie-beam. These will receive compressive thrusts from the rafters. With larger spans, these trussing members are increased in two ways. In one the tie-beam is supported by several verticals, and from the foot of each, struts are placed to the rafters, E. In another, the trussing will take the elementary form of F in a small span, multiplied in a larger one as in G, H. Another type of roof is the queen-post, in which two posts reach from the tie-beam to the rafters and are connected to a straining beam above, J, K. Diagonal struts abut between the bases of the queen-posts and the rafters, and often from the middle of the straining beam to the rafters, J.

In roofs of large span it is usual to camber the tie-beams in order to lessen the lengths of the struts. This should be done in moderation only, as the stresses on the rafters are increased by cambering.

The principals are the skeletons of the roof. They have to sustain the purlins, or bars which are laid along and connect the principals, and these again support the common rafters on which the actual coverings of slates or tiles are laid.

The loads on roofs are mostly of a dead or static character, due to the weight of the entire principals and their coverings, to which is added about 6 lb. per square foot for snow. Wind pressure has to be allowed for at a rate of from 30 to 50 lb. per square foot in different situations. The pressure is estimated as coming on one side of the roof. The actual pressure on an inclined roof will be much less than a vertical pressure allowed for, and will vary with the angle of roof.

The arched form of roof is a favourite design for large spans. The ribs may be built up of joist section, or more commonly of open lattice bracing. There is much similarity between bridge and roof design, an arched roof being similar to an arched bridge, but with a much greater rise. And like bridges, roofs may have rigid, or hinged principals. In the latter case they have three articulations, one at the centre, and one over each pier. The latter may be at the ground level, the two portions at which the principals are divided extending from the centre to the ground. The calculation of strains with an arch free to pivot is much simpler than with a rigid arch. Roofs covering wide spaces such as railway stations are generally either of the arched form, or a repetition of spans of moderate width, supported on girders carried on columns. These do not differ in any essential from the single roof spans, employed for shops and warehouses.

Roof principals are built of timber, iron, and steel. In timber work very wide margins of safety are allowed, partly because of the imperfections in the timber, and the liability to decay, and partly to compensate for the weakening effects of notching and morticing. Shoes of cast iron are employed to receive ends, and to take the pull of tie-bo
by means of strap
iron and steel,
sively for
tions b

into disuse, except sometimes for roofs ll span. The angle sections are now ɔd almost exclusively for members in ssion, and flat plates for the attachments ods. The simplicity of these fittings ɔ way in which they lend themselves to ve work renders them cheap, light, and ; means of construction.

250 and 251 show typical roofs, for ops. The latter figure is from one of the undries of the Lancashire and Yorkshire y.

t's Blower.—*See* **Blower.**

e Driving.—This is a rival to belt driv- long distance transmission. It is a very rice, having been introduced by Mr Combe of Belfast in 1856, a rope of having been used. About 1863, manilla ere substituted with success. Flexibility essential in a rope drive, because if a too rigid, or is run over small pulleys nvolves stiff and hard working, the fibres ɪr one another, breaking up the structure, lucing the fibres to a powdery condition. inish this is the reason why some manu- rs lubricate their ropes during the of spinning. A mixture of plumbago llow is used by the C. W. Hunt Co. ɔments of the most importance in rope are the diameters of the pulleys used, e sectional form of the grooves. Here ifferences exist in practice. With regard ɪeter, the late Mr James Combe adopted lowing as the minimum diameter of for various sizes of ropes :—

liam. rope,	3 ft.	diam. pulley ;	ratio	1 to	28·8
,, ,,	4	,,	,,	1 ,,	32·0
,, ,,	5	,,	,,	1 ,,	34·3
,, ,,	6	,,	,,	1 ,,	36·0

ɔs where large pulleys are inadmissible, ɪe alternative is to use smaller ropes on pulleys, but increase the number of giving a multiple form of drive.

'peed of Ropes—Horse Power.—Mr Combe l a speed of about 3,300 feet per minute. ɔeds up to 5,000 feet have been frequently ed. There is no advantage in such a eed, and it appears that 4,000 feet can- exceeded with advantage, for centrifugal ɪnd the friction of the atmosphere become counteracting agencies. A table by the C. W. Hunt Co. of New York shows that the horse

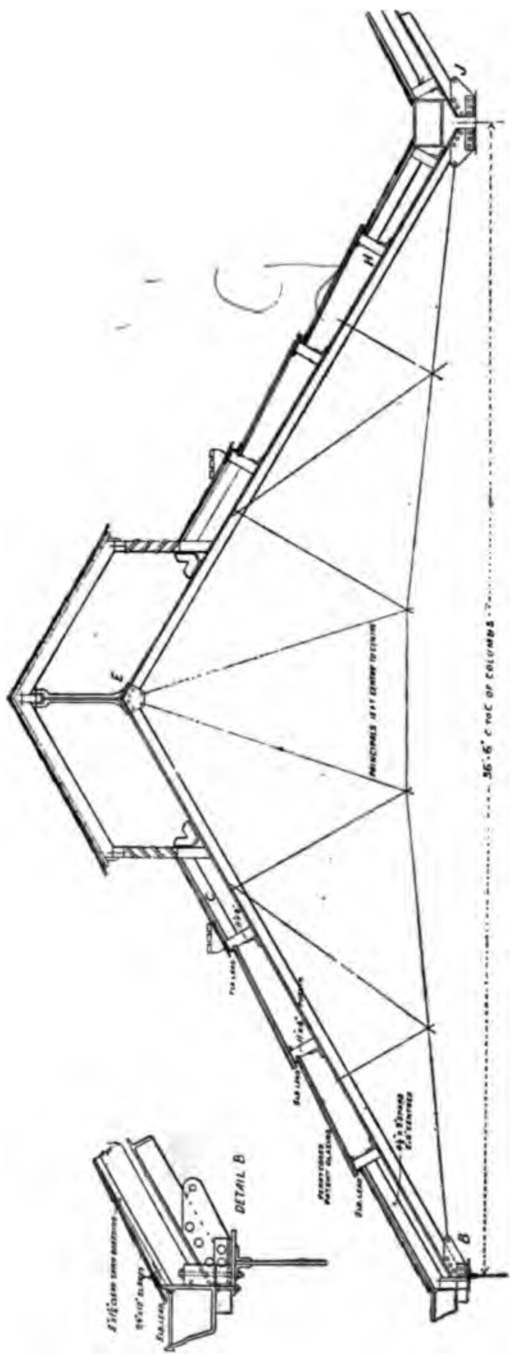


Fig. 251.—Roofs.

power lessens as the speed exceeds about 80 feet per second.

TABLE OF HORSE-POWER OF MANILLA ROPES. Speed of ropes in feet per minute.

Diameter of Rope in Inches.	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	6,000	7,000	8,400	Smallest Diameter of Pulley in Inches.
$\frac{1}{2}$	1·45	1·9	2·3	2·7	3·0	3·2	3·4	3·4	3·1	2·2	0	20
$\frac{5}{8}$	2·3	3·2	3·6	4·2	4·6	5·0	5·3	5·3	4·9	3·4	0	24
$\frac{3}{4}$	3·3	4·3	5·2	5·8	6·7	7·2	7·7	7·7	7·1	4·9	0	30
$\frac{7}{8}$	4·5	5·9	7·0	8·2	9·1	9·8	10·8	10·7	9·3	6·9	0	36
1	5·8	7·7	9·2	10·7	11·9	12·8	13·6	13·7	12·5	8·8	0	42
$1\frac{1}{4}$	9·2	12·1	14·3	16·8	18·6	20·0	21·2	21·4	19·5	13·8	0	54
$1\frac{1}{2}$	13·1	17·4	20·7	23·1	26·8	28·8	30·6	30·8	28·2	19·8	0	60
$1\frac{3}{4}$	18·0	23·7	28·2	32·8	36·4	39·2	41·5	41·8	37·4	27·6	0	76
2	23·1	30·8	36·8	42·8	47·6	51·2	54·4	54·8	50·0	35·2	0	84

This Table assumes an arc of contact of not less than 170°.

Mr Combe's basis for horse power was, that ropes will transmit for each 100 revolutions per minute made by the pulley, as follows:—

Rope $1\frac{1}{4}$ in. diam.	on a 3-ft.	pulley	will transmit	5	I.H.P.
,, $1\frac{1}{2}$,,	,, 4 ,,	,,	,,	8	,,
,, $1\frac{3}{4}$,,	,, 5 ,,	,,	,,	11	,,
,, 2 ,,	,, 6 ,,	,,	,,	15	,,

In ropes working under the most favourable conditions, running horizontally at good speeds, with the bottom rope acting as driver, from 20 to 25 per cent. may be added to these figures. But if pulleys are situated too closely, and ropes run vertically they must be lessened by from 20 to 25 per cent.

With a given velocity the *weight* of rope required for transmitting a given horse power is the same, irrespective of its size. Hence the convenience of being able to substitute several smaller ropes for one or more larger ones. Placing the pulleys at an ample distance apart is very important, because a large amount of sag has to be allowed (*see* Fig. 253, A), the only limit to which is the tendency to slip. A tight rope will wear out much more rapidly than a slack one. The amount of sag is taken on the driving side, and should be constant at all speeds, but that on the slack side will increase as speed lessens.

Stress on Ropes.—The ultimate strength of a rope 1 in. in diameter is about 7,000 lb. But an enormous factor of safety is allowed, equal to about $\frac{1}{30}$th to $\frac{1}{35}$th of the breaking strength. The problem is rather of a dynamic than a static character, and overstraining and chafing wear out a rope with extreme rapidity. Among the things which militate against the long life of ropes are loosening and untwisting and friction of the strands, chafing and friction in pulley grooves, friction of adjacent ropes having too much sag, and pulleys too small for the size of ropes.

Splicing.—The strength of the rope is no greater than that of its splice. But the large margin allowed still leaves from $\frac{1}{20}$th to $\frac{1}{25}$th margin over the strength of the splice. A long splice is essential. The C. W. Hunt Co. give the following as the proper length of splice for ropes of different sizes:—

Diameter of Rope.	Length to allow for Splicing.	Diameter of Rope.	Length to allow for Splicing.
In.	Ft.	In.	Ft.
$\frac{3}{4}$	9	$1\frac{1}{2}$	16
$\frac{7}{8}$	10	$1\frac{3}{4}$	18
1	12	2	20
$1\frac{1}{4}$	14		

Applications of Rope Driving.—There are two main systems of rope driving adopted, both of which originated in Belfast; one is termed the *multiple* system, the other the *tension* system.

The Multiple System.—In this a number of separate and independent ropes are used, running side by side in a series of grooves. The commonest example of this kind is the rope flywheel drive from large mill engines to pulleys on shafts, driving machines on different floors, Fig. 252. Tl
England, and b
When well d
smooth and
A large n

transmit power, and the chafing and wear be reduced to the minimum possible. The slight

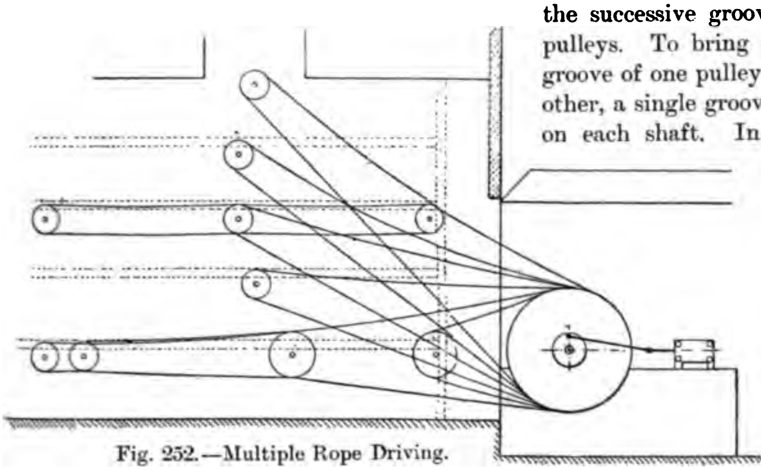


Fig. 252.—Multiple Rope Driving.

disadvantage is that the tension in the different ropes is apt to vary, due to unequal stretching. But should this, or a fracture occur, the engine need not be thrown out of action long, because a spare rope can be substituted in a few minutes.

The Tension System.—In this a single endless rope is used, hence termed also the *single rope system*, with the advantage that the tension is equal throughout. A single rope passes round the successive grooves of driving and driven pulleys. To bring the rope back from the last groove of one pulley to the first groove of the other, a single grooved loose pulley is mounted on each shaft. In another design a tension pulley is mounted away from either shaft, and the rope, after passing successively through the grooves of driving and driven pulleys, goes over the tension pulley, which conducts the rope from the last groove of one pulley into the first groove of the other pulley. These methods were adopted in the first place in cases where the centres of shafts were situated too close together to permit of effective rope driving. But they have been extended to long drives with advantage. The location of the tension pulley is not arbitrary. The best is that in which a single pulley is used with one bending only of the rope, and which takes place in the

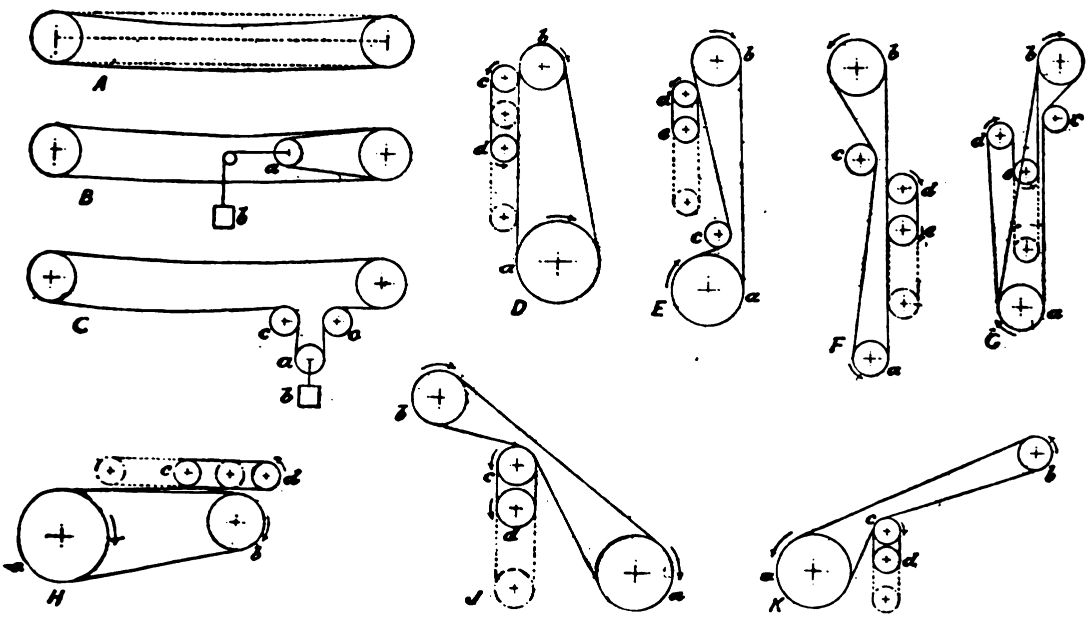


Fig. 253.—Single Tension Rope Driving.

same direction as that over the main pulleys. Then the thing to be avoided is a small pulley which would distress the rope. The less favourable condition is that in which the direction of bending of the rope is reversed. Numerous and varied are the arrangements which have been devised under this system in mill driving. There is a limit to the amount of rope that a single tension pulley can take up. The maximum length should not exceed 3,500 ft., nor the number of grooves exceed ten. Hence more than one tension pulley has to be used in some cases. There are various methods of mounting them.

In Fig. 253 various rope drives on the single tension system are illustrated. B is a simple example. The tension pulley *a* keeps the rope sufficiently taut by the load of the suspended weight *b*. In C the tension pulley *a* is pulled down by a suspended weight *b*, but the rope is bent over two guide pulleys *c*, *c*, and as the direction of bending is the reverse to that over the main pulleys, the fibres of the rope are strained more than when the bending is in one direction only. D is a vertical drive for an elevator; *a*, 14 ft. diameter, having eighteen grooves, drives *b*, 7 ft. 8 in. diameter, 130 ft. away; *c* is an idler pulley, *d* one with two tensions, that is two endless ropes are used. The dotted outlines of *c* and *d* indicate the vertical movement of their travel, which is necessary to compensate for the varying lengths of the rope, due to stretch. The rope is 1½ in., and transmits 900 HP. Another elevator drive is shown at E. *a*, 14 ft. diameter, driving *b*, 9 ft. 6 in. diameter, 134 ft. away, with seven grooves each; *c* is an idler 6 ft. diameter, also with seven grooves, and *d* is an idler pulley 6 ft. diameter with one groove, leading to the tension pulley *e* with a vertical range of 20 ft. The rope is 1½ in., transmitting 260 HP. F is another elevator drive, with 1½-in. rope, of 350 HP., similar to the last, but arranged differently. *a* is a nine-grooved pulley, 6 ft. diameter, driving *b*, 9 ft. 6 in. diameter, 122 ft. away; *c* is a nine-grooved idler, 4 ft. 6 in. diameter, and *d* is a single-grooved idler leading to the tension pulley *e*, both 4 ft. 6 in. in diameter, with a vertical travel of 25 ft. G is a vertical drive from a four-grooved pulley *a* to *b*; *c* is the four-grooved idler, and *d* the single-grooved idler, *e* the tension pulley, with 18 ft. range of vertical travel. H is a main drive in the horizontal style of transmission, the pulleys *a* and *b*, 20 ft. and 12 ft. diameter respectively having each thirty-six grooves; *c* is a tension pulley, having three tensions, *d* the idler, having one groove. The rope is a 2-in. one. J is a diagonal drive from a twelve-grooved pulley *a* to *b* with 1½-in. rope. *c* is an idler with thirteen grooves, one of which is loose, driving to the single tension pulley *d*, with 15 ft. of vertical travel. K is another diagonal drive with 1½-in. rope between pulleys *a* and *b* with eleven grooves; *c* has one loose, to drive to the tension pulley *d*. These examples are from the practice of the Webster Manufacturing Co.

The tension sheave is an important element in the single rope system. It takes up the slack, to permit of which it has its bearings in a carriage which is free to move under the pull of the weight. The endless rope is carried over the first groove of the first sheave, thence over the first groove of the second sheave, back over the second groove of the first sheave, then to the second groove of the second sheave, and so on until it has been passed over the last groove of the first sheave, whence it is carried round the tension sheave.

The tension pulley should be so placed that it shall take the slack of the rope from the driving rather than from the driven sheave. The idler must lie against the slack side of the rope. An extra groove is always required to lead the rope back to the tension sheave. This extra groove can be interposed as an idler sheave, or it may be located in the driver, or driven sheave as most convenient. If the extra groove is on the driving sheave, as when the tension is taken therefrom, it is fast, being part of the sheave. If, however, the extra groove is on the driven sheave, the tension being taken from there, it must be loose, so allowing the tension to take up the slack of the rope direct from the driving sheave. If the tension is taken from an idler sheave, which is the best practice, the driver and driven sheave have both the same number of grooves.

have concluded that it would be more advantageous ind two volumes of this Encyclopædia in one volume. t is, volumes One and Two, Three and Four, Five Six, Seven and Eight, and Nine and Ten, are each d together ; thus publishing the work in five bound volumes, instead of ten.

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OF

PRACTICAL ENGINEERING

AND ALLIED TRADES

A PRACTICAL AND INDISPENSABLE WORK OF REFERENCE FOR THE MECHANICAL ENGINEER, DESIGNER, DRAFTSMAN, SHOP SUPERINTENDENT, FOREMAN AND MACHINIST.

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EDITED BY

JOSEPH G. HORNER, A.M.I.MECH.E.

AUTHOR OF "PRACTICAL METAL TURNING," "MODERN MILLING MACHINES," "PATTERN MAKING," "TOOLS FOR MACHINISTS, AND WOODWORKERS," ETC., ETC.

ASSISTED BY A CORPS OF PRACTICAL MEN, EACH A SPECIALIST IN THE SUBJECT OF WHICH HE WRITES.

PROFUSELY ILLUSTRATED.

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The Encyclopædia

OF

Practical Engineering and Allied Trades.

Rope Pulleys.—These are of sections which ensure a firm grip of the rope, without producing such excessive friction as would damage the fibres. There is a difference made when the pulley has little power to transmit, and that chiefly static, or when it is dynamic. In the first case the rope may bed in the bottom of the groove, in the second it does not reach the bottom, but bears on the sides. To increase the grip in the first design, the wheel is frequently *waved*, that is the groove does not run in one plane, but goes to right and left of the middle plane, with a rather long sweep, say of 6 in., or 8 in. Such wheels are used on the overhead travellers which are operated by a dependent rope from below. In pulleys for power transmission at high speeds, the sides generally slope at an angle of about 45° towards each other. Other details are of lesser moment, but some standard forms are shown.

Fig. 1 illustrates various grooves. A represents a very deep groove suitable for *crossed* ropes, that is driving when a single rope passes over multiple-grooved pulleys. The pitch is wider than that for parallel single rope drives, and the grooves are deeper. B is a grooving for half-crossed driving, or when the axes of the pulleys stand at 90° in relation to each other. Here the grooves are shallow to allow the ropes to enter and leave without rubbing too much against the sides. C is the deep groove as made by the C. W. Hunt Co. It differs from others in having a flat bottom, and from some in having straight sides. The object is to design a groove which will have the same coefficient of friction when the rope is worn as when it is new, and one that can be tooled without difficulty. D is the same groove, with a medium one adjacent, with lettering for the formula used, thus:—

$d=$ diameter of the rope.
$a=d-\frac{1}{8}$ in.
$b=0{\cdot}5\ d.$
$c=0{\cdot}7\ d.$
$e=d+\frac{1}{4}$ in.
$f=1{\cdot}375\ d+\frac{3}{8}$ in.

A shallow groove is also made in which the rope stands slightly above the edges of the rim. E represents a groove introduced by Messrs Combe & Barbour for driving shafts which are not parallel, and when the angle of the shafts exceeds 3°. F represents a very common form of groove. This, and C as shown, or with a radius at the bottom, are usual designs, adopted with only a difference of 2° in the angle of the sides. The sections are reproduced to correct scales. For suitable diameters, *see* **Rope Driving.**

One of the great advantages of rope driving is that it lends itself readily to driving between shafts that are not parallel, and shafts at various angles, and for crossed rope drives. More can be done in this way than with leather belts.

Ropes.—These are made of flax, hemp, or manilla fibre, or of cotton, sisal, or wire. *See* **Cotton Ropes, Wire Ropes.**

A rope is formed of threads or yarns twisted

in one direction. These are made up into strands twisted in the opposite direction, and the strands into ropes, the twist again being reversed, the object being to neutralise the tendency to untwisting consequent on stretch. Ropes have either three or four strands: the latter must have a central core, which the three-strand rope does not require. Experience has proved that a three-strand rope is much more durable than one with four strands. The reason doubtless lies in its greater flexibility. A central core does not conduce to flexibility, and this quality is of the highest importance. *See* **Rope Driving**. Ropes being formed by twisting the fibres, explains why a new rope stretches to a considerable amount before it reaches a stage at which its length remains permanent. Hence the reason why a new rope has to be re-spliced two or three successive times before its stretch is taken out. The sizes of ropes are given as their girth or circumference, and their weight in pounds per fathom.

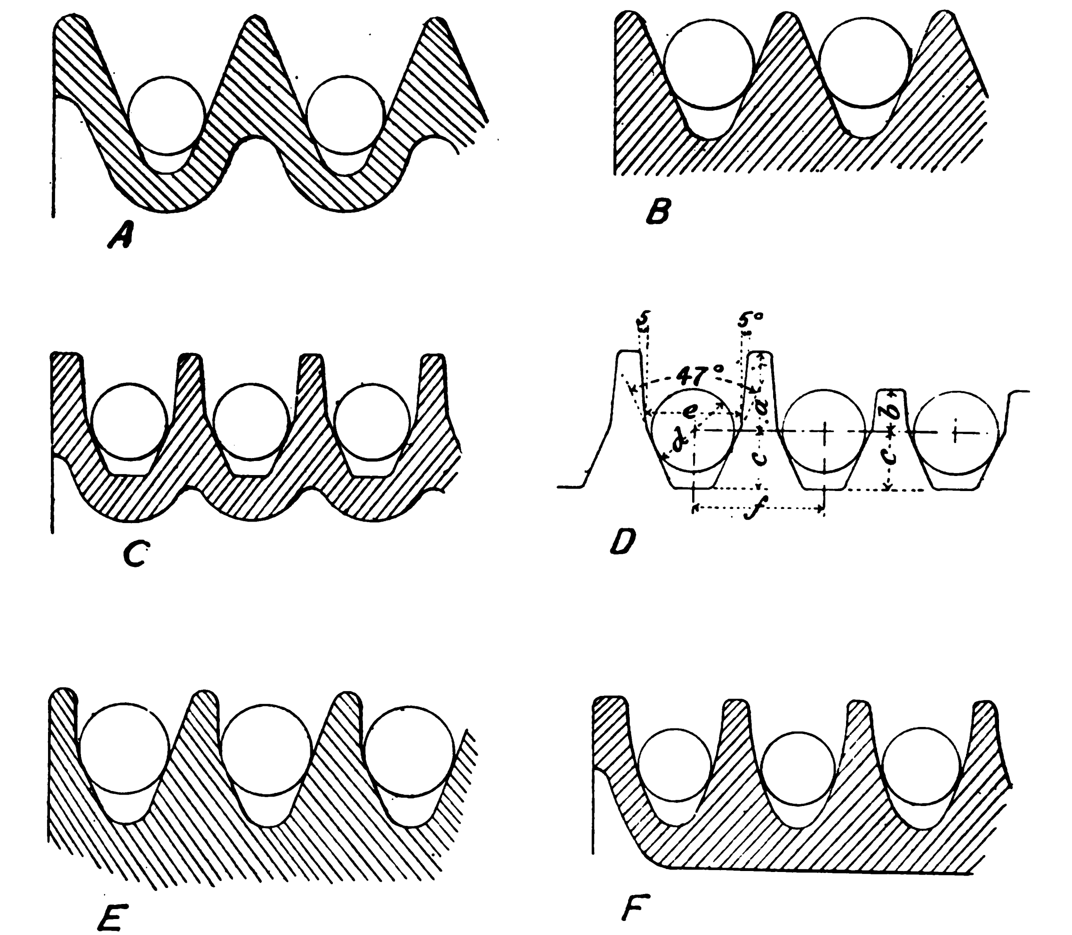


Fig. 1.—Rope Pulley Grooves.

Manilla.—This derives its name from Manilla, in the Philippine Islands, and comes from a species of plantain, the *Musa textilis*, one of the Banana family. The stem of the *Abaca* attains a height of 15 to 20 ft., and it has a very smooth surface. The fibre derived therefrom is white, and of a silky appearance, and very light. The fibres are made up of elongated bast-cells, about a quarter of an inch long, and of irregular form. Although the fibre is rough to the touch,

it may be pointed out that this is not due to the substance in itself, but solely on account of the treatment to which it has been subject, such as tearing or pulling apart of the cells. The fibres are very strong longitudinally, but not transversely.

The manilla plant is cut when it is from two to four years of age, just previous to its flowering. The envelope is stripped off, and the coats are left to dry, being then split longitudinally into narrow strips. Scraping is then done until nothing but fibres remains. The bundles are then in a state to be shaken into separate threads; they may or may not be then washed, and dried, following which they are picked, to separate the better qualities. The stuff is then packed in bales ready for export.

In the rope works the bundles are opened, the stuff shaken apart, and sprinkled with oil to facilitate its subsequent treatment. The operation of *scutching* is then carried out, the stuff being passed over cylinders covered with steel prongs, which remove the dirt and odd bits, at the same time straightening the fibres. Machines called *breakers* then take the fibre in hand, and pass it over two endless chains provided with upstanding pins; the second chain runs quicker than the first, so that the fibres are drawn or combed out into a ribbon or *sliver*. Other machines termed *spreaders* and *drawing frames* further treat the fibre, drawing it again and again, until finally a *finisher* leaves the material in the form of soft ribbons ready for spinning.

Jennies or spinning frames spin the sliver into yarns on to bobbins, which are then taken to the forming and laying machines that twist the yarns into strands, and the latter into ropes. But large ropes are made up in the rope walk, a long shed, at one end of which the bobbins carrying the yarn are placed, the yarns being passed through holes in a *face-plate*, and then through tubes, to the hook of a forming machine, running on rails along the shed. The mechanism on the machine imparts a twisting motion, so forming the yarns into strands. These have now to be laid into rope, and two *laying machines* are employed, at opposite ends of the track. One machine has but a single hook, turning in one direction, all the strands being attached to this hook, while the other machine has a hook for each strand, turning in the opposite direction. The strands are inserted in grooves in a conical wooden *top*, which travels along as the laying proceeds, and *tails*, or short pieces of rope help to lay the strands regularly.

In the old *rope walks*, before machinery was introduced, the ropes were laid by a workman, who carried a large bundle of fibres around his loins, the ends of which were attached to a wheel turned by a second man, as the spinner walked backwards down the shed, paying out the fibre. When sufficient yarns were ready they were twisted into rope.

Leather Ropes.—Attempts have been made to utilise ropes of leather, but with little success, the ends of the strands becoming frayed out. The vee-shaped rope with sections riveted across a continuous belt is used for expanding pulleys. The so-called chain-rope is useful, but it is really a form of link belt.

Ropes versus *Belts.*—From the experiments at Lille conducted by a commission of experts it was ascertained that the power expended in different kinds of transmission was as follows, showing that ropes and belts absorb about the same amount of power:—

	Gross power.					
Ropes -	158·54	I.H.P.	with slip	of	0·33	per cent.
Cotton belt	159·67	,,	,,	,,	0·78	,,
Leather belt	158·84	,,	,,	,,	0·96	,,
Leather belt	160·23	,,	,,	,,	0·78	,,

Rose Bit.—*See* **Bit.**

Rose End, or **Rose Jet.**—The perforated strainer or nozzle at the end of a hose pipe.

Rose Reamer.—*See* **Reamers.**

Rosin.—*See* **Resin.**

Rotary Blower.—*See* **Blower.**

Rotary Engine.—An engine in which a piston or pistons rotate within a cylinder. Scores of forms have been designed and patented, and failed. In many the central boss which carries the rotating piston or pistons is located centrally in the cylinder, in which case the piston is rigid. In many others it is situated eccentrically, and then the piston slides radially in a groove in the body. A few rotary engines have achieved a fair measure of success, and on the face of it there seems reason to suppose that the rotary design should be preferable to the

reciprocating, since there is no inertia to be overcome at reversal, no dead centres, and no complicated valve gearing. But the objections to the rotary engine are great. There is the difficulty of making steam-tight packings. The steam is used wastefully, having to fill the steam space at each revolution without expansive working. The only way to economise is to design engines in series.

Rotary Machine Tools.—A large group which is represented chiefly by the lathes, milling machines, drills, boring machines, grinders, and sub-types and special designs of each. The common feature is that the work or the tool rotates, or both, so producing surfaces which are either circular, or plane, parallel, tapered, or profiled. The three divisions into lathes, milling machines, and grinders correspond with the use of three distinct types of tools—the single-edged, the multiple-edged, and the grinding wheel. Much rivalry exists between these in those operations which can be performed with equal facility on either group of machines, though not often with equal accuracy and economy. But notwithstanding different views regarding results, each machine type has a field all its own without rivalry. The specific functions of the members of these groups will be found treated under numerous heads.

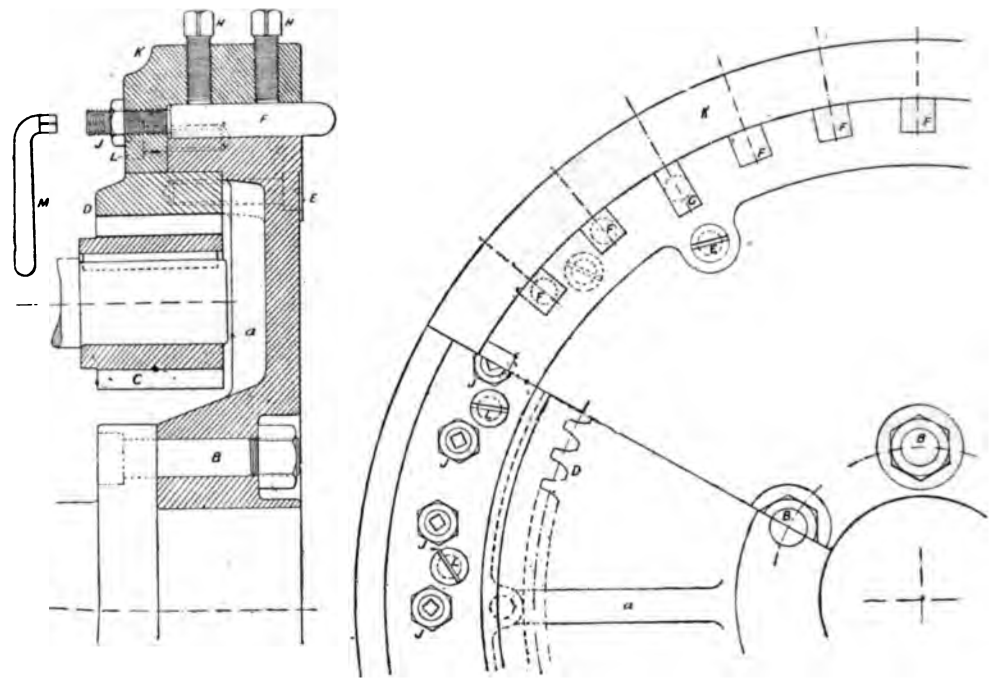


Fig. 2.—Face Milling Cutter.

Rotary Planing, or Face Milling.—Refers to the use of inserted-tooth face milling cutters for producing plane faces. Their employment has grown very much, but the original forms have been long in use. They show to most advantage, not in fine finishing, but in heavy roughing down. They are used for facing the feet of castings for bolting to other surfaces, for facing the ends of girders, and for removing material in quantity preparatory to the finer finishing by grinding or planing. Such cutters have their limitations, because they are only suitable for facing on plane areas.

In their simplest form, the face cutters are tool points, held simply with set-screws in holes in the cutter head, and generally set at an angle, which gives a suitable front rake to the tool points. But in the best designs provision is made for fine adjustments of the cutters in the heads by means of screws, as in Fig. 2. In many cases the edge of the disc is

ed at an angle, and flat steel tools inserted, secured by cylindrical wedges driven in s between the slots. In a few cases the ers are cast in their head, and are satisory in working, but no adjustments or wals can be made.

ig. 2 illustrates a large face milling cutter by gyes, Ltd. The body measures 2 ft. 9½ in. liameter. It is stiffened with six ribs *a*; bolts B secure it to the machine spindle. overcome the torsion due to heavy work, pinion C, and ring of teeth D are provided rotating the head. The ring is secured to plate by the cheese-head bolts E. The cutter block is made for use on a horizontal milling machine.

Fig. 3 illustrates a cutter 10¼ in. diameter, by a German firm, the Maschinen-Fabrik Lorenz. The body A is grooved to receive eight cutters B, which have a segmental thread cut on their inner edges for fine adjustment—effected by the tapered operating screws C, recessed in the neck to receive the tommy D. The cutters are pinched securely in their grooves by a ring, E, threaded to fit the body, and having an internal portion tapered to draw over the cutters by the turning of the ring with the tommy F.

The machines in which these heads are used

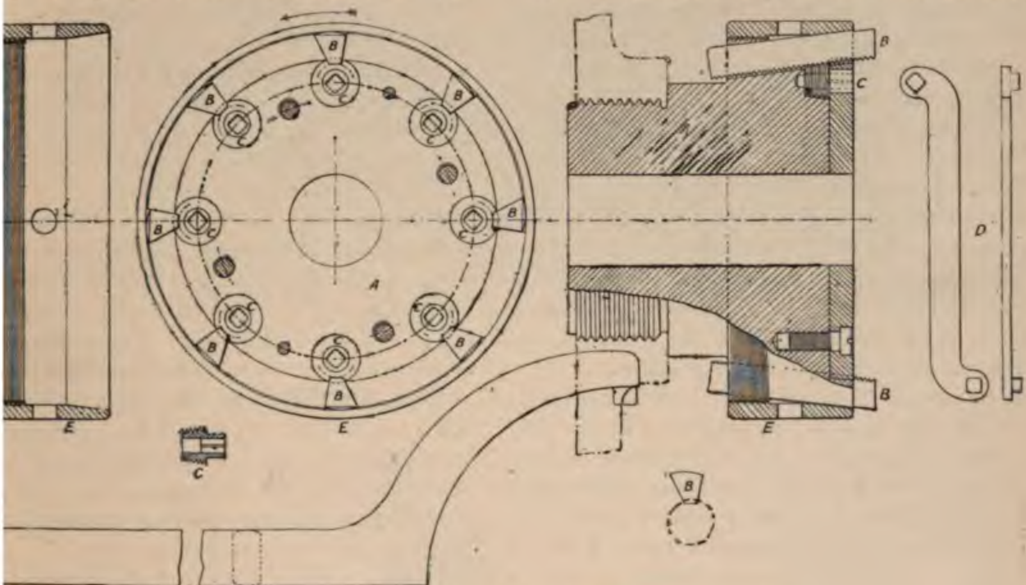


Fig. 3.—Face Milling Cutter.

ers F, G are for roughing, and finishing ectively, and are inserted in slots in the at an angle of 5° right hand, and are hed by the set-screws H, and adjusted ards by the screws J. These screws are ed into a ring, K, which is fitted and bolted he body by the screws L. The right-hand e, it will be noted, shows the heads of both of screws, being a part front, and part back. The adjusting screws J have square holes heir heads to receive the tommy M. They have lock nuts. There are thirty-two hing tools F, 1 in. square in cross-section, two finishing tools G, 1½ in. by ¾ in. This have either travelling saddles, or travelling tables, the work being fixed in the one case, and moving in the other. For very heavy pieces it is more convenient to let them be stationary, and travel the cutter. The object to be tooled is then bolted to a large plate, and the cutter head saddle slides along a bed at the side. Fig. 4, Plate I., shows a very large cutter head, with a disc 120 in. in diameter, carrying seventy-five tools. The saddle is mounted upon a bed 26 ft. long, affording a travel of 11 ft. An electric motor provides the driving medium, and there are three speeds to the disc, and three reversible feeds to the head. A rapid

power adjustment is also produced for setting to different positions, all the motions being controlled by the attendant, who stands on the platform. This machine was built, together with a similar one, to be mounted on a floor plate, so that both ends of a piece of work could be tooled across simultaneously.

A 48-in. rotary planer is illustrated in Fig. 5, Plate I.; it is of special type, the saddle being mounted on a circular base on which it may be swivelled to set the cutter head at various angles. The saddle has a traverse of 8 ft., and the head can be moved in or out to the extent of 3 in. for setting the depth of cut. The work is clamped to the table on the left-hand side. The driving is effected by the pulleys to the right, connected by a shaft to the rotatory and feeding mechanisms.

Rotary Puddling Furnaces.—These, first introduced in 1853, have been constructed in numerous designs. Though used to a considerable extent in the United States and Germany, they have not found much favour in Britain. The principal furnaces which have been built or survived, and achieved a considerable measure of success, are the Danks, the Siemens, the Pernot, the Crampton, and the Jones.

The Danks Furnace.—This is little used now, though the parent of others. As in most rotary furnaces the axis of revolution is horizontal. The grate is fixed, and differs from ordinary puddling grates in being supplied with jets of air above the surface of the fuel, and in having a closed ash-pit into which a blast of air is introduced. The furnace rests on live rollers and is encircled by a toothed ring which is rotated by a pinion. The shell is made of segments with internal ribs running longitudinally which hold the fettling. One end of the furnace is open to the fire-grate, the other to a movable flue which communicates with the chimney. The flue is suspended in order to permit of turning it aside to open the mouth of the furnace for the withdrawal of the puddled ball. The firing hole and the mouth of the flue are kept cool by means of water jackets.

The rotary puddling furnace at the works of Messrs Schneider & Co. at Creusot comprises the three portions—the fixed hearth, the rotary furnace, and the movable flue or smoke-box. In these the waste gases go from the smoke-box to heat a multitubular boiler. The furnace is divided by a separator which divides the charge into two equal parts, and which is water cooled. The furnace lining is comprised of a double iron casing, which is cooled by a stream of water. It is rotated by a steam engine through two toothed rings and pinions, so that in the general design this is built after the Danks model. It is found that, using the same ores, the rotary furnace produces iron more free from traces of phosphorus and sulphur than the hand puddling furnaces do. They are used for producing iron for the manufacture of Siemens-Martin steel. Each furnace yields fifteen one-ton charges in twelve hours.

Rotary Squeezer.—*See* **Squeezers.**

Rough Coat.—Relates to the first application of loam in building up a loam mould, or core. It is coarser and thicker than the succeeding finishing application.

Rough Cut.—*See* **Files.**

Rough Dimensions.—The sizes of castings and forgings which have extra allowance made for tooling. The rough dimensions may be $\frac{1}{16}$ in., $\frac{1}{8}$ in., $\frac{1}{4}$ in., or more in some cases than those of the casting or forging after machining.

Roughing Down.—Signifies the rapid or heavy reduction of material preparatory to finishing operations. It applies to the rolling of finished iron and steel in roughing rolls, and to the removal of the outer metal from castings and forgings in machine tools.

Rapid roughing down is an economical operation, because less time is occupied than as though a lesser amount of material were reduced, or removed by more frequently repeated applications of the rolls in the first case, or of the cutting tools in the second. There are limitations to both, but up to those it is judicious to rough as heavily as possible, and finish finely. Some slight amount of distortion is liable to result from roughing, which fine finish removes. In the work of cutting tools a difference is generally made in the shapes of those for roughing and finishing. Feeds are also generally coarser or more rapid for finishing than for roughing. Some machine tools are now built specially strong for heavy roughing, leaving the finishing to be done on another machine. The

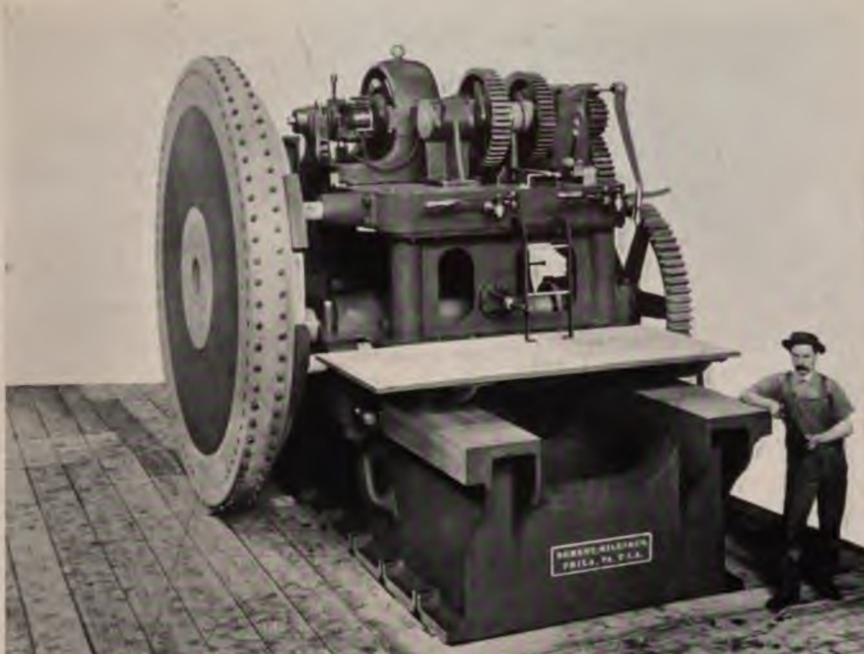


Fig. 4.—LARGE ROTARY PLANING MACHINE. (The Niles-Bement-Pond Co.)

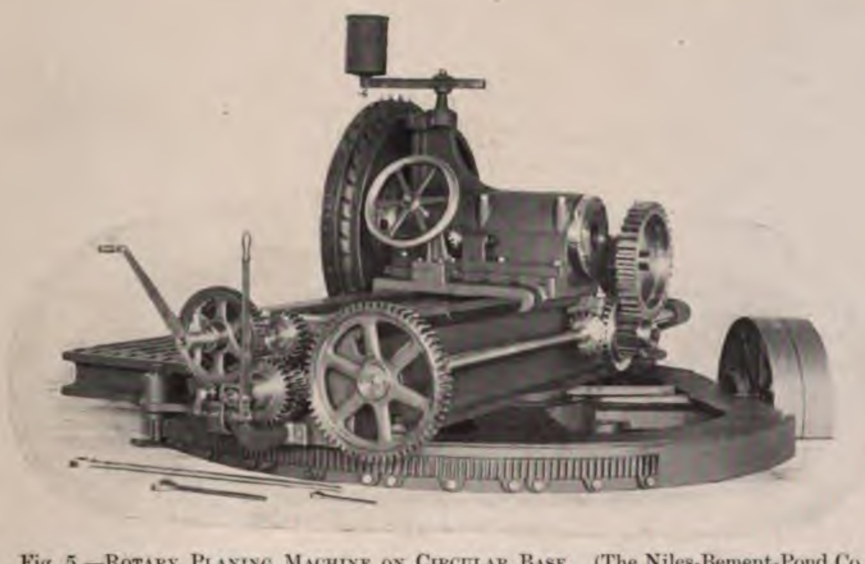


Fig. 5.—ROTARY PLANING MACHINE ON CIRCULAR BASE. (The Niles-Bement-Pond Co.)

To face page 8.

advent of the high-speed steels has created a powerful impetus in favour of heavy roughing down, so that in some classes of work it has become a most important factor in economical production.

Roughing Rolls.—The first set of rolls in any iron or steel works, in which the greater part of the reduction of sections is effected. They have larger amounts of *draught* than the finishing rolls have.

Roughing Tools.—Tools used by metal and wood workers for removing the greater bulk of material preparatory to the fine finishing operations. They are mostly of round-ended, or of prismatic form. The first penetrates with a concave section of cut, the second takes a broad flat shaving. The first is the more efficient, but the second compensates by its width of cut for its shallowness. It also leaves a smoother surface than the round-ended tool does. In wood turning the gouge is the roughing tool.

Round File.—*See* **Files.**

Round-Nose Tool.—One used by turners in wood and metal for finishing accurately concave sections. It acts by scraping. Tools of various widths and radii are kept. The radius of a round-nose need not correspond with that to be turned. It is often less, but cannot be greater. Though most roughing tools have convex cutting edges, they are not understood when the term round-nose is used. The essential distinction is that the roughing tool has top rake, the round-nose has none.

Rounds, or **Round Bars.**—Bars of circular section rolled in iron and steel. Rivet bars, stay bars, and shafting are rounds, but the first two are of special quality to pass certain tensile and ductile tests; the last has to be rolled straighter than commercial rounds.

Rounds are rolled in diameters ranging from $\frac{5}{16}$ in. or $\frac{3}{8}$ in. up to 12 in. But bars below $\frac{1}{2}$ in. and over 3 in. are usually charged as extras, and the extras become very high over 6 in. diameter. Diameter advances by $\frac{1}{64}$ in., $\frac{1}{32}$ in., $\frac{1}{8}$ in., and $\frac{1}{4}$ in. in various stages. Extras are charged over about 15 ft. lengths. All bars up to $6\frac{1}{2}$ in. can be had in iron or steel. Steel alone over that diameter.

Rivet bars are made from $\frac{31}{64}$ in. up to $1\frac{1}{2}$ in. in iron and steel. Rivet bars in steel for boiler quality must have a tensile strength of 24 to 27 tons per square inch, and an elongation of not less than 25 per cent. in a length of 8 in. Ship rivet bars have a strength of 26 to 30 tons with the same elongation. *Stay bars*, 27 to 30 tons with not less than 20 per cent. elongation in 8 in.

Reeled bars are those which have been passed through a reeling machine, having two conical rollers with their axes set at a slight inclination to each other. The effect is to finish the bars perfectly smooth and straight, and accurate to diameter.

Rubber.—*See* **Glasspaper Rubber, India-rubber.**

Rubbing.—Taking the shapes of the teeth of a worn or broken wheel, with the object of obtaining the shapes of new teeth to replace the old. Or a rubbing may be taken from an existing wheel from which to make a new one to work with. It is done by laying a sheet of white paper against the ends of the teeth, and rubbing the surface of the paper until sufficient dirt or grease is transferred to the paper to indicate the outlines correctly. The paper is then termed a *rubbing*. A more accurate method is to cut a thin templet to fit between several adjacent teeth.

Rubbing Board.—A flat piece of board with a smooth face, being held in the hand and used by moulders for imparting a neatly levelled surface to broad areas of foundry moulds, before final sleeking with the trowel.

Rubble Work.—Roughly broken stone which is used in civil engineers' work for filling in large spaces. Before the introduction of moulded concrete blocks, rubble was largely used for structures under water, stability being afforded by the natural slope of the materials, and by facings of masonry which served as wave breakers. At present rubble is chiefly reserved for heartings, and is often cemented together with liquid concrete. Broken rubble is also employed in mixing concrete for blocks.

Rudder Frame.—*See* **Stern Frame.**

Rule Measurement.—This has much less prominence in the workshop than hitherto, on account of the increasing employment of the fixed and the micrometer, and sliding gauges. The objection to direct rule measurement is

that it cannot be relied upon, since the sense of sight alone has to be depended on for results. Even if dividers are used to take off dimensions, slight discrepancies are noticeable. The rule is relegated therefore to the less accurate classes of measurement, and for testing the sizes of materials, as well as for the work of the carpenter and patternmaker. The work for which, perhaps, the greatest accuracy is expected of rules is now that of lining out, where dividers play an important part in transferring sizes from the rule to the work.

Rule of Three.—The rule of three is a method by which the fourth term in a **Proportion** may be found when the other three are given. The rule is based on the fact that the product of the "means" equals the product of the "extremes." If 2 castings require 10 cwt. of metal, then 4 castings will obviously require 20 cwt. of metal. This proportion is set down thus:—2 : 4 : : 10 : 20. The numbers 2 and 20 are extremes and 4 and 10 are means. And $2 \times 20 = 40$, and $4 \times 10 = 40$. If therefore any one of these four terms were missing it could be found. Take such a question as this: if 16 castings require 94 lb. of metal, how much metal will 20 castings require? Here we have two quantities of castings, and only one of metal, and therefore 94 lb. of metal will go in the third place. The other two go in the first and second places, and to decide in what order these two must be set down, whether 16 castings or 20 castings shall come first, the question must be considered whether more or less than 94 lb. will be required. If more, the order will be 16 : 20 : : 94 : ? If less, 20 : 16 : : 94 : ? As more than 94 lb. of metal are required the first case is correct. The means are multiplied and their product divided by the one extreme,

$$\frac{20 \times 94}{16} = 117{\cdot}5 \text{ lb.}$$

In every question, therefore, two points have to be decided: (1) of what kind is the unknown quantity, because the other term of the same name goes in the third place; and (2) will the unknown quantity be greater or less than this third term? if greater, then the larger of the two remaining quantities goes in the second place, if less, the smaller goes in the second place.

Rule of three enters largely into pulley questions, and it is not always easy in these questions to decide whether the required answer must be greater or less than the third term. A 12-in. pulley which runs 200 revolutions per minute drives a 5-in. pulley. How fast is the latter running? The number of revolutions clearly goes in the third place. But will the number of revolutions be greater or less for the smaller pulley? Evidently greater. The statement is then:—5 : 12 : : 200 : ? = 480 revolutions per minute. Conversely, a 5-in. pulley which runs 480 revolutions per minute is required to drive a machine at 200 revolutions, and it is required to know what sized pulley is to be on the machine. The size of the pulley goes in the third place. Now to run slower than the driving pulley, the driven pulley must be larger, and the larger number of revolutions goes in the second place, 200 : 480 : : 5 : ? = 12 in.

Rules.—Staffs or strips of metal or wood having subdivisions of the yard or the metre marked upon their faces, and used for direct application to work, or as a means of setting dividers or compasses. The wooden rules are employed chiefly by wood-workers, and they range from lengths of a foot up to several feet, in the latter case being provided with brass plates let in at the divisions, and a short length of brass rule at the end, graduated into the finer subdivisions. Hinged, or folding rules of boxwood are much used by patternmakers and carpenters, the usual length being 2 ft., with one, or three joints. Graduations are placed on both sides, along each edge, often with eighths on one side and sixteenths on the other, scales being placed on the inside edges as well in many cases. The rules are so jointed and cased in brass on the edges and ends that the wood does not come into contact with work, and the wear, and the warping are consequently delayed for a considerable period. The contraction or shrink rules are used by patternmakers, and are longer than standard by the amount of shrinkage which occurs in castings; some are marked for iron only, some for iron, brass, and steel. Angular divisions are sometimes placed on the circular hinge of a jointed rule, to serve as an indication of the angles which the legs make at various openings, a

which is useful for approximate working. ıles are employed chiefly by draughts- l others for the more delicate classes of ment, where hard usage is not so likely. ıriations exist in the classes of divisions the better styles of boxwood and ivory ıany being very fully graduated. A iding jaw incorporated with a rule is or measuring rods, plates, &c., by direct

steel rules used by metal-workers are de plain, and folding, but the latter fly wanted for work, such as outdoor , where it is inconvenient to carry a rule. But for accurate work a solid ous rule is the only kind that can be pon for constant use. Hinged steel en have a locking catch at the joint to arms at right angles, though this cannot ıded on for accuracy after a little wear. duations on steel rules are carried to ıounts than is the case with wood, ths being put on some; they can be f with finely pointed dividers, with or a magnifying glass. Metric and English s are combined in one rule, on its sides, as a convenience for those who work by the two standards. The asses of steel rules are spring tempered hey do not tend to become permanently rough, damage or accidental pressure. d rules are also made; the edges and lo not, therefore, wear so rapidly as is with soft rules. Thin flexible rules ly for laying around curves to measure rrectly; the metal is of watch-spring out $\frac{1}{100}$ in. thick.

g special types of rules may be men- he square and triangular forms, the rules, used for small openings, their ing only $\frac{3}{16}$ in.; the short rules, about long, and provided with a lateral handle, he edge may be presented to confined s where the length of even a 6-in. rule e prohibitive of its use. Rules with ons at the end, lying at right angles to the main divisions, are supplied for r purpose. Hook rules have a small t screwed to the end, and lying flush so that the hook may be butted up against the edge of the work to measure from it quickly; the advantage is most apparent when edges are rounding, rendering it difficult to place the end of the rule exactly flush. If the hook is not required, it can be turned back out of the way. Key seat, or box rules are triangular, that is with two flats lying at right angles, and they are laid on shafts, to scribe parallel lines thereon, for key seats; graduations are usually placed along one or both edges. The circumference rules are most useful in dealing with circles; they have ordinary inch subdivisions along one edge, and on the other the equivalent circumferential measurement of the circle. Thus, opposite the first division of 1 in. there would be 3, and the fraction equivalent to 0·1416 in.

Rumble.—*See* **Tumbling Barrel.**

Runaway Motion, or **Safety Stop.**—A device fitted to an engine governor to prevent racing in case of parts of governors breaking, or a governor belt slipping, or a main belt breaking. It comes into action when the balls rise too high, and in some cases if they fall too low.

Runner Head.—The lump of metal which fills the pouring basin and ingate of a mould. A feeder head is similar, or identical in form. These heads are often knocked off the castings while red hot. They are in request in the foundry for putting into ladles of metal which is too hot for the purpose for which it is required, and the temperature is lowered by the melting of the heads.

Runner Pin.—Also termed *Runner stick*, *git*, *git pin*, or *git stick*. The pattern which is used to form the runner opening of a mould. It is tapered for ready withdrawal, and of shapes suitable to varied kinds of work. The commonest form is of cylindrical section. But many are square, or oblong, and stout, or thin. They are kept in stock in all dimensions, in wood generally, but in iron in some of the smaller sizes, and in brass or lead in the form of *sprays*.

Running Away.—The racing of an engine, due to sudden relief of the load when the governor is inoperative, or not sensitive enough.

Running Centre Chuck.—The common centre, illustrated under **Driver**, as distinguished from the dead centre lathe type.

Running Down.—The sequence of melting in a foundry cupola. The metal is said to be *down* when it has accumulated in sufficient quantity below the tuyeres to allow of being tapped out. Also relates to the turning down of a bar with a box tool, or a hollow mill.

Running Out Fire.—*See* **Wrought Iron.**

Running Tackle.—Any combination of blocks and ropes, as distinguished from a fixed pulley.

Run Out.—The escape of metal from a foundry mould during pouring, in consequence of a badly made joint.

Runway.—The overhead track employed for a travelling crane or hoist; chiefly applied to those in workshops, for overhead travellers, or for pulley blocks. In the first case the rails are supported on girders resting on corbels in the wall, or separate vertical columns; in the second the tracks are suspended from beams.

Russian Sheet Iron.—A valuable quality manufactured to the east of the Ural mountains. It is characterised by a dark grey glossy surface, the result of hammer finishing. Particular care is exercised in all the stages of manufacture. The cast iron, obtained from local ores, is smelted with charcoal, and converted into wrought iron by puddling, or in fineries. The puddle balls are rolled into bars about 5 in. wide, by $\frac{1}{4}$ in thick. These are cut up and reheated, and cross rolled in packets of three sheets. These are sheared to size, and annealed in a wood fire, and subsequently hammered

Rust.—Rusting proceeds rapidly after it has commenced to form. This is explained by the fact that the rust—the hydrated ferric oxide—is only the final stage in a series of chemical changes. Carbonic acid appears to start corrosion, forming a ferrous carbonate. This is dissolved in carbonic acid moisture to form ferrous bicarbonate. The latter becomes decomposed in the presence of air, and moisture, forming the hydrated ferric oxide, an intermediate product being the magnetic oxide. The hydrated ferric oxide is strongly hygroscopic and absorbs moisture from the air, so hastening the formation of more rust. It is also believed that the fact that rust is electro-positive to iron favours the formation of more oxide.

Protection against rust in rolled iron and steel plates is best afforded by cleaning them first from scale, by a process of pickling before the application of paint. On such mechanically cleaned plates one or two applications of pure red lead in pure raw linseed before the final coats of paint will afford protection for an indefinite period. A coat of hot boiled oil is a good substitute, and it is the practice in some good firms to coat all castings and forgings and plated work thus before doing any work upon them, especially when they have to be erected out of doors. But while cast iron requires no preliminary scaling, wrought iron and steel should have such treatment, because rust once started will increase beneath the scale and paint. Many cases have occurred on the one hand of iron work properly protected lasting for half a century unimpaired, and on the other hand of rapid corrosion.

Cast iron is better able to withstand corrosion than wrought iron or steel, and white iron than grey. It is said that cast-iron car wheels immersed in fresh and sea water for many years show less corrosion on the chilled portion than on the body.

It has been stated that wrought iron not properly painted may be expected to rust at the rate of $\frac{1}{8}$ in. from each surface in from fifteen to thirty years. If properly protected the wear is inappreciable.

Rusting Patterns.—Iron patterns are preserved from rust in foundry moulds by being rusted, and then varnished, or coated with bees' wax. A bright pattern would not retain either, but rusting imparts a surface which can be protected with these coatings. The iron is rubbed with a weak solution of hydrochloric acid, or with a strong solution of sal-ammoniac in water, which when dried off leaves the surface rusted.

Rust Joint.—A joint made between the flanges of tank plates, and in many socketed joints of water pipes. An open space of about $\frac{3}{8}$ in. or $\frac{1}{2}$ in. is left, and into this a mixture of iron borings and sal-ammoniac, moistened with water, is *stemmed*, or driven hard with a caulking iron. The sal-ammoniac cements the particles of iron, forming a mass of metal and rust, making a solid joint in the course of a day or two. A little sulphur is sometimes added, but it is not essential.

S

dle.—Denotes the base portion of a est, or drilling head, or milling head, slides along its bed or support. Also a *carriage*.

dle Flange.—A pipe flange which is to fit a cylindrical pipe or other vessel.

dle Key.—A key which fits on the curve haft instead of being recessed into a key These are only suitable for very light or shafts too small to receive a key

dle Tank Engine.—A locomotive, the f which is arched over by the water tank. itable for local and contractors' service.

: Edge File.—*See* **Files.**

: Load.—The load on a structure or r which it is able to sustain without g stress exceeding the elastic limit. It d by the factor of safety permissible, ries much with the nature of the loading, r dead, or live, or of the nature of sudden and with the capacity of the material to leterioration. From the latter point of he safe load may have to be reduced ome period of service, as is especially e in steam boilers, and in iron and steel ibject to corrosion.

ty, Factor of.—*See* **Factor of Safety.**

ty Hoist.—*See* **Lifts.**

ty Hook.—A crane hook fitted with a bar or bridge across the opening, which s risk of the chain becoming jerked off.

ty Ladle.—*See* **Casting Ladle.**

ty Lamp.—This was invented by Sir rey Davy about the year 1818. Its le is illustrated by holding a piece of uze (about seven hundred meshes to a inch) an inch or two above a jet of gas, niting the gas above the gauze. The able gas below the gauze does not burn the wire conducts away the heat of the bove so rapidly that the gas below does not reach the temperature of ignition. In the Davy lamp the flame is surrounded by gauze, and though fire damp may be abundant, no flame can pass through the gauze to explode it. On the other hand, explosive gases penetrate the gauze and burn harmlessly, their presence being denoted by a pale blue cap round the flame. Specially designed lamps such as the Ashworth-Hepplewhite-Gray lamp are used for ascertaining the percentage of gas present. The early forms of safety lamp have been discarded, partly because, owing to improved ventilation, air currents in the mine have a greater velocity than formerly, and the flame may therefore be blown against, or even through the gauze. Of improved types the Marsant is largely used, others are the Clanny, and the Mueseler. The oil used is either seal oil or rape oil, in the proportion of two parts to one part of paraffin or petroleum. Portable electric lamps are only sparingly used, for although they illuminate the working face better than oil lamps, they give the miner no indication of the presence of dangerous gases. Electric glow lamps are however used in the roadways and pit bottoms. Explosions of coal dust or fire damp still occur even with modern safety lamps, and some of the causes to which these accidents are attributed are classified in Home Office Reports as being due to (*a*) gauze becoming red hot, (*b*) oil or soot on gauze taking fire, (*c*) flame driven through gauze by ventilating current, (*d*) flame driven through gauze by improper handling.

Safety Valve.—A lift valve, which is set to open at a certain pressure, the amount of which is determined by a loaded lever, or by a spring of definite tension strength, or by a dead load. The variations of these main designs are not very numerous, and they affect lesser details of construction chiefly. The **Dead Load Safety Valve** is used less than the other types, and for Lancashire boilers chiefly.

Lever Safety Valves.—In these, Fig. 6, the ratio between the long and the short arm of a loaded lever is used to determine the pressure. The valve is between the fulcrum and the weight, and the steam pressure on the valve is many times greater than the weight. The pressure on the area of the valve is equal to the steam pressure in pounds per square inch, multiplied by that area. The loading of the lever, and the radius at which it takes place regulates the blow-off, but the weight of the lever has to be taken into the calculation, and the more so the lower the steam pressure. The formulæ given below are used.

Let W = the load in pounds at the end of the lever.

L = the length in inches from the load to the fulcrum.

w = the weight of the lever in pounds.

g = the distance in inches of the centre of gravity of the lever from the fulcrum.

p = the pressure in pounds of the steam per square inch above the atmospheric pressure.

v = the weight of the valve in pounds.

A = the area of the valve.

l = the distance in inches between the centre of the valve and the fulcrum.

Then, to find what load, W, should be hung on the lever—

$$W = \left\{(p \times A) - \left(v + \frac{w \times g}{l}\right)\right\}\frac{l}{L}.$$

Having the load, and the pressure given, to find the length, L, of the lever—

$$L = \left\{(p \times A) - \left(v + \frac{w \times g}{l}\right)\right\}\frac{l}{W}.$$

Having the load given, to find the steam pressure, p, at which the valve will open—

$$p = \left\{\frac{(w \times g) + (L \times W)}{l} + v\right\} \div A.$$

The lever of a safety valve is usually graduated, and a notch filed at each graduation to permit of regulating the pressure by movement of the weight to any notch. The lever is either bent down at the fulcrum, or the pin over the valve is pivoted loosely on the lever. The object in each case is to avoid a lateral thrust on the valve at the time of lifting, due to the fulcrum being above the point where the pin and valve are in contact. Most valves are properly made with a conical recess on the top, Fig. 6, in the bottom of which the pin makes contact. The effect is to hold the valve in a horizontal position instead of allowing a tilting movement to occur over its seat.

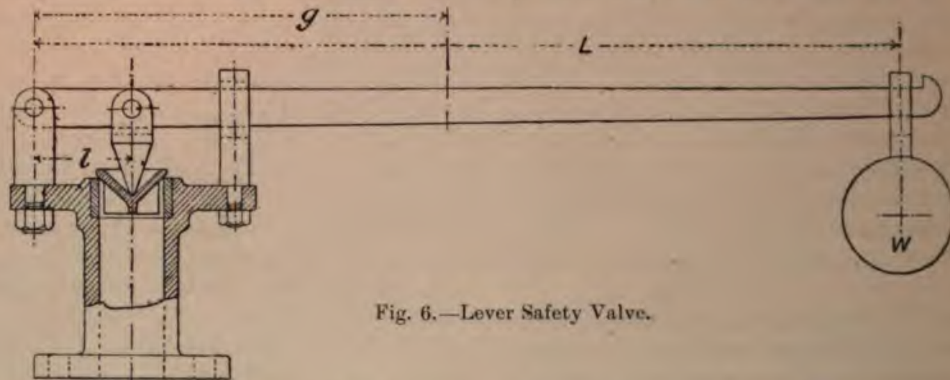


Fig. 6.—Lever Safety Valve.

The two main differences in valves lie in the shape of the joint which they make with their seatings. They form either mitre, or flat-faced joints. Mitre joints make an angle of 45°, with from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. width of faces in contact. Flat faces may be from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. wide. An objection to the mitre is its liability to stick. Flat valves are used to a much greater extent than formerly. The guidance of the valve is either by a central pin, or by wings. The first is nearly obsolete. Several boiler explosions have been traced to the bending and sticking of a valve spindle. With wings there is no risk of bending, but they will stick unless sufficient play is allowed, say from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. in small, and large valves respectively. A

valve may be an easy fit when cold, but will be liable to stick when heated if the valve is of gun-metal, and the casing of iron. In good work the casing is bushed with gun-metal seatings.

An objection to the lever valves is the facility with which they can be tampered by overloading. If a lever is longer than necessary for the weight and pressure, the pressure can be increased by moving the weight farther out. Or heavy masses in any case can be attached to the weight. Or a wedge can be inserted in the guide which is fitted to prevent the lever rising too high. The way to prevent overloading is to keep the valve under observation, to secure the weight with a lock, or to employ a bonneted lock-up safety valve, closed and secured with a padlock. The dead weight safety valve has the advantage that overloading becomes apparent. As valves are liable to stick on their seats, the lever should be lifted occasionally

Spring Safety Valves.—There are two kinds of these, the ordinary type, and the Ramsbottom. In the common valve a coiled spring occupies a position corresponding with the weight at the end of the loaded lever valve. One end of the spring is anchored to the end of the lever, the other to a lug attached to the boiler. The objection to a spring is that its power of resistance increases as it is pulled apart by the lift of the valve, so that a higher steam pressure than the normal is required to resist the tension of the extending spring. It is usual to allow a load of 1 lb. pressure per square inch on the valve, to 1 lb. pressure on the spring, which simplifies calculation. The lift at the end of the lever is therefore measured by the rise of the valve, multiplied by its area in square inches.

Areas of Valves.—These are regulated usually in reference to the square feet of fire-grate, a rather indeterminate basis, but no more so than heating surface, its alternative. Fire-grate area is taken in conjunction with steam pressure, since it is obvious that valve area must be dependent on the volume of steam generated in a given period, and the accumulation of which it has to prevent. Different Governing Bodies at home and abroad lay down rules which vary from each other, and to which manufacturers of valves have to conform. The Board of Trade tables give minimum areas of valves per square foot of grate for a large range of pressures, for natural draught, which valve areas must be exceeded considerably when forced draught is used. But for similar boilers worked similarly, and to the same pressures, the volume of steam will vary as the grate area. To obtain fire-grate area, the length is taken from the inner edge of the dead plate to the front of the bridge, and the width between the sides of the furnace on the top of the bars at the middle, their length, and the two dimensions, in feet being multiplied together. It is stipulated that in no case shall a valve be less than 2 in. in diameter, and there must be two valves to each boiler.

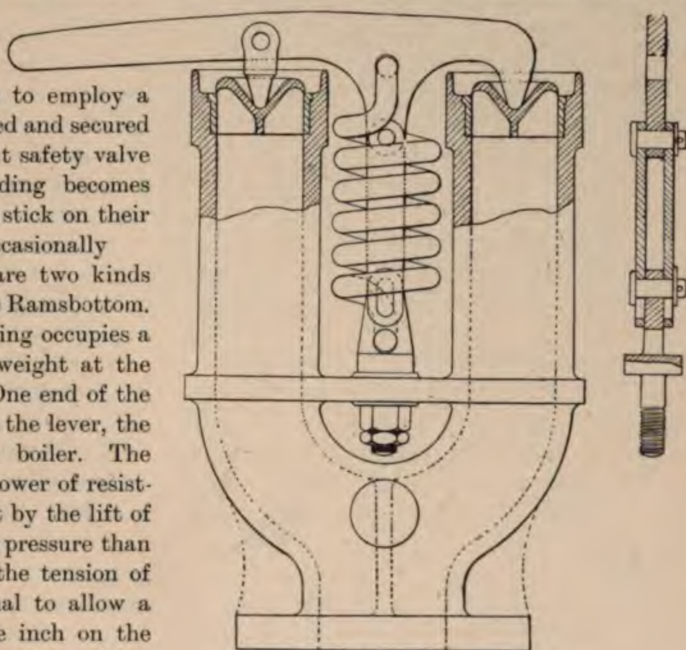


Fig. 7.—Ramsbottom Valve.

Ramsbottom Valves.—In these a central spring controls the action of two valves. The spring is attached to the lever in a position lower than the points of pressure of the lever on the valves. The opening of one valve therefore relieves the pressure on the other, which would not be the case if the spring attachment were higher than the points of pressure.

Fig. 7 is a section through a Ramsbottom

valve by Messrs Alley & Maclellan, Ltd., with a section through the lever and check gear to the right. The chest is of iron, the valves, seats, and fulcrum pins of bronze, and the lever and check gear of mild steel. It is made in bores of valve ranging from $1\frac{1}{2}$ in. to 5 in. Another valve of the same kind is shown in Fig. 8, with the difference that a flange is fitted at the side for use in covered boiler houses where it is necessary to carry the waste steam away. This involves bringing the valves

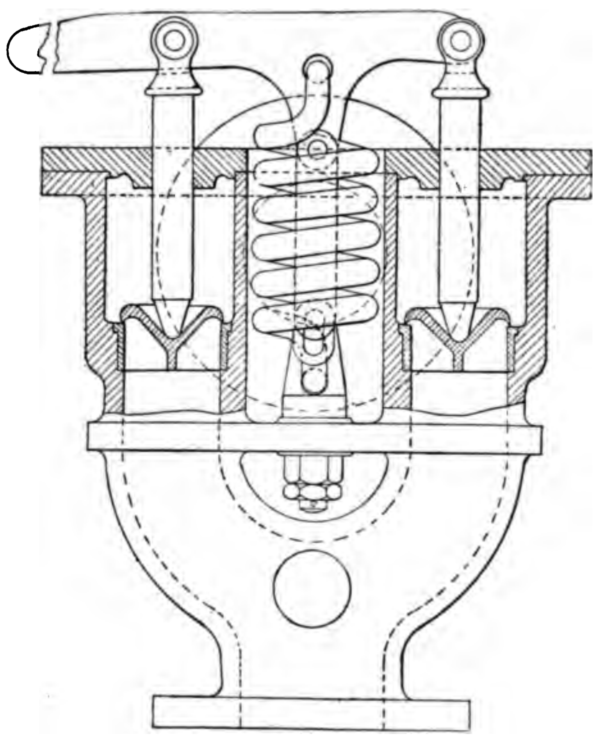


Fig. 8.—Ramsbottom Valve, with confined Exhaust.

and seatings lower down in the chest. It is made in the same dimensions as the previous valve, and both for pressures up to 200 lb. per square inch.

Direct Spring Loading.—The valves for marine engines are of this type, the valve stem being prolonged into a casing, and encircled by a coil spring which has a maximum lift equal to one-fourth the diameter of the valve. The pressure being direct is preferable to lever valves, and as the latter would be affected by the rolling of the vessel they are not used in marine service. Spring valves are single, or double. They are enclosed at the top so that they cannot be tampered with. Provision is made for lifting the valve by means of screw easing gear to test its freedom of action. It is worked by hand from the engine room or the stokehold.

The Board of Trade rule for the size of springs is —

$$\sqrt[3]{\frac{S \times D}{C}} = d.$$

Where—

S = the load on the spring in pounds.
D = the diameter of the spring (from centre to centre of wire) in inches.
d = the diameter, or side of square, of the wire in inches.
C = 8,000 for round steel.
C = 11,000 for square steel.

The Pop Valve.—This is the name given to a valve in which the steam blows off sharply with a pop. This result is obtained by causing the escaping steam to act sharply on an additional area above the valve, which then compresses the spring suddenly. The valve also closes sharply when the pressure is reduced by about 3 per cent.

Accumulation.—This signifies the ability or otherwise of a valve to carry off surplus steam under the most unfavourable conditions. Many boiler explosions have been traceable to valves which allowed the pressure to run up while blowing off. Several things may conduce to accumulation, the principal being insufficient area. It is usual to test this by firing hard, with feed and stop valves closed, for from twenty to thirty minutes, when the accumulation of pressure should not exceed from 5 to 10 per cent. When a valve is open to a height of one-fourth of its diameter it is fully open, because:—

$$\frac{\text{diameter}^2 \times \cdot 7854}{\text{diameter} \times 3 \cdot 14159} = \frac{\text{diameter}}{4}.$$

Contributory causes of accumulation are tightly fitting valves, stiffness of springs and connections, due to rusting, and whatever tends to produce these results.

Though the Board of Trade and other bodies give rules for the strength of safety valve springs

d and square steel, manufacturers test ılves before sending them out.

—The drop of a rope or belt between in the horizontal direction. Some of sag is unavoidable, and a moderate s essential to avoid too great tension. y an evil when it is excessive, inducing and swaying of the belt.

ers.—The boxes in which the castings ced for annealing in the process of malleable cast iron.

mmoniac, or **Ammonium Chloride,** —This was formerly prepared by dis- he ammoniacal liquor of gas works, ing the ammonia gas with hydrochloric l evaporating the liquor. It is now, , mostly obtained from the sulphate, a d solution of which is mixed with a lution of common salt; on evaporating, sulphate separates out, and ammonium is left in solution. In appearance, sal- ιc is a colourless, tough, translucent, nass, soluble in water, and with a saline It is used as the electrolyte in Leclanché ; in the printing of textile fabrics; a flux in soldering. Sal-ammoniac is give bronze a good antique colour. It largely by engineers in making rust for tanks, and pipes.

ometer.—A form of hydrometer de- or estimating the proportion of salt in r of a marine boiler. Salt, when in ecomes deposited on the tubes and nd the object of the salinometer is to ι when the water becomes too salt, at age a definite quantity is blown off, aced with fresh *make-up*.

alinometer is graduated to show the gravity of the water at a definite ure, usually 200° Fahr., which would be ie temperature of water freshly drawn boiler. The instrument has a gradu- m, having a bulb loaded with shot or to keep the stem upright in the water, ther forming a float. The stem above is graduated thus:—

ater contains on an average 5 oz. of ie gallon, or 1 lb. of salt in 33 parts of r. $\frac{1}{33}$ part therefore is the unit, termed *ee* of saltness; 10 oz. of salt to the gallon is $\frac{2}{33}$, or *two salt waters*, and so on. The latter is the limit desirable, above which blowing-off should be done, as well as regular scumming.

The salinometer is graduated by floating it first in fresh water at 200° temperature, and marking the level of the water, and then by floating it in sea water of the average $\frac{1}{33}$ degree of saltness, and at the same temperature, and marking again. A definite quantity of the sea water is taken and boiled down to half the quantity, which will give twice the concentration of salt as the average. Then the instrument is floated, and marked again for $\frac{2}{33}$. Then by boiling down to a half again, and once more, to give $\frac{3}{33}$ and $\frac{4}{33}$ of saltness. The spaces between these marks are then subdivided to indicate ounces.

The graduation at a definite temperature is essential, because the volume of water expands with heat, and if tests were made at different temperatures, the instrument would not record alike correctly. It is also essential that the tests be made in an open vessel at atmospheric pressure.

Salt.—A salt is produced by the combination of an acid and a base. Thus the action of sulphuric acid on zinc oxide (a base), produces zinc sulphate (a salt), and water:—

$$ZnO + H_2SO_4 = ZnSO_4 + H_2O.$$

The hydrogen of the acid is replaced by the metal. When the whole of the hydrogen of the acid is replaced by the metal, a *normal* salt is produced, but when only part of the hydrogen is displaced, an *acid* salt results. Thus K_2SO_4 is a normal salt; $KHSO_4$ is an acid salt. The nature of a salt, whether normal or acid, is not revealed by its action on litmus. The combination of a normal salt with a basic oxide or hydroxide produces a *basic* salt:—

$$Pb\begin{cases} ONO_2 \\ ONO_2 \end{cases} + Pb\begin{cases} OH \\ OH \end{cases} = 2Pb\begin{cases} ONO_2 \\ OH \end{cases}$$

Acids whose names end in *ous* form salts whose names end in *ite*; and names of acids ending in *ic* form salts with names ending in *ate* (as in the first equation).

Salting.—A certain amount of salt is allowed to accumulate on the interiors of marine boilers.

Frequent blowing off, and scumming are adopted to prevent too great an accumulation. It should not exceed $\frac{2}{33}$ salt water, or 10 oz. of salt to the gallon. *See* **Salinometer**.

Salvage Work.—The recovery of vessels which have sunk in shallow water, or have been partially damaged by contact with rocks or by collision. About a thousand vessels are lost every year all over the world, and of these a small proportion are partly or wholly salved. Associations for this work exist in most maritime countries. The most notable among recent works of this kind are the *Montagu* at Lundy, which, however, was unsuccessful, and the *Suevic* off the Lizard. The latter was cut in two, the comparatively undamaged portion towed to Southampton, and a new part made in Belfast and towed to Southampton and riveted to the old. Another piece of work fresh in the memory is the salving of the submarine A1.

The present article deals with the engineering equipment, and the character of the operations which have to be performed.

The work of salvage includes engineering operations in their widest scope, carried on under extreme difficulties. There is no such thing as cut-and-dried repetitive operations, since each piece of work involves methods of treatment specially adapted for it. Hence the salvage vessels are floating workshops, carrying materials and tools to suit all possible emergencies which may arise. A large proportion of these involve work done by divers. *See* **Diving Operations**. Cutting, drilling, blasting, and patching, have to be done as much under as above water. Powerful centrifugal pumps and engines are necessary for pumping water out of compartments, and also from pontoons when such are attached to a sunken vessel. An electric light installation is required to supply light by incandescent lamps for the work done under water. Wells' lights are also used on board, or on shore in the event of the temporary failure of electric light. Plenty of wire rope is required, and stores of all conceivable kinds. A workshop is well equipped with machine tools for all kinds of possible operations, boring, planing, bolt making, forging, riveting; and a carpenters' department for heavy timber work.

A pneumatic plant, and tools are an essential part of the equipment. It includes an air compressor, chipping, and riveting hammers, drills for wood and metal. These will work under water.

A telephone provides means for the divers to communicate with the vessel, the conducting wires being passed through the air pipes. The life line is used for passing materials up and down.

The methods of raising vessels and their cargoes have to be varied with circumstances. Fair-leads on the ship are used for lifting heavy weights out of vessels by the rise of the ship with the tide, the vessel dragging them at high tide to shallow water. Some cargoes which swell under water have to be broken out with break-out gear. This is used for dealing with jute, cotton, grain, and coffee. Vessels are raised bodily by the flotation of two salvage vessels ranged one at each side, steel wire hawsers being passed under the wreck. The latter is then towed into shallower water and grounded, and lifted again at the next tide, so that in four or five such operations a sunken vessel may be beached.

In some cases pontoons are riveted on the sides of vessels, and when all is ready, the water being pumped out of them, there is sufficient buoyancy to lift the wreck. At the same time bulkheads and rooms often have to be emptied by pumping before the vessel can be floated.

Frequently large holes in the ship's plating have to be covered up before pumping can be attempted, and these may be partly or wholly under water. Timber is generally used to cover these up, the deals being laid outside, and caulked with oakum or cement and held up in place with bolts. Weak parts may have to be stiffened with plates or beams. Ragged portions are often severed by drilling, or by small blasting charges, if under water.

Sand-Blasting.—This process, introduced by B. C. Tilghman in 1870, depends for its action upon the driving of innumerable grains of fine sand or other material by the agency of steam or air against a surface, which is thereby cut or ground away, as though a grinding wheel had been passed over it. As, however,

sand is in the form of a stream, it is able penetrate recesses and work over irregular faces which could not be treated by a solid asive agent. Each grain of sand does its re of the abrasion, but as its effect is ex- nely minute, the most delicate operations be performed and the blast be controlled h precision. Among the work done by the

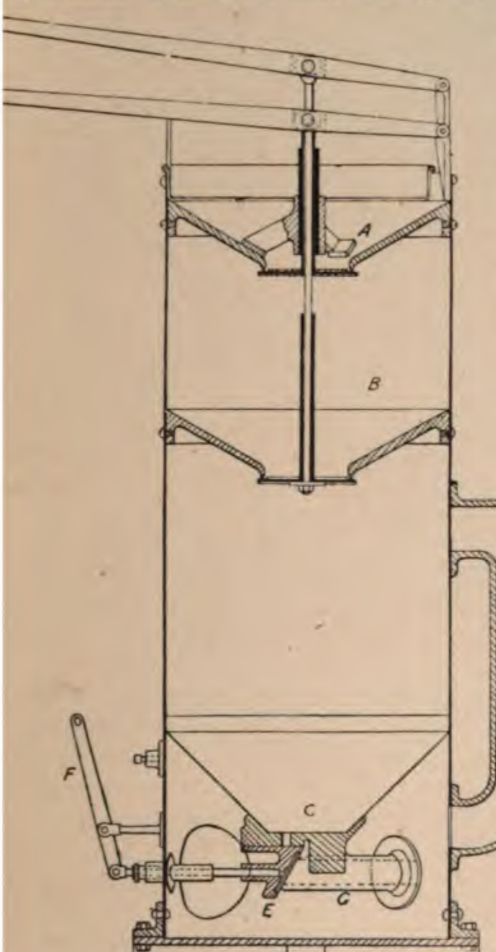
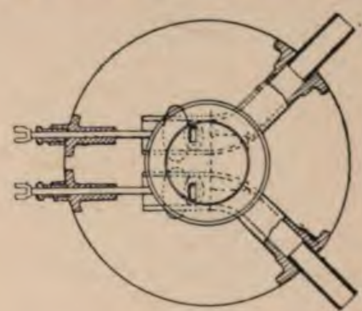


Fig. 10.—Sand-Blasting Apparatus.

d-blast may be mentioned that of cleaning ious kinds of objects, to remove dirt or e, as on castings and forgings prepara- to tooling, or to enamelling, galvanising, ing, tinning, &c. Cleaning brazed joints, n cycle frames, dirt and paint from plating, in ships, and rust from ironwork gener-ally. In the finer classes of operations are included file sharpening, carving, or engraving in stone, marble, &c., the decoration of stone, glass, pottery, &c., and various classes of granulation or roughening up on glass, wood, celluloid, &c. A peculiarity of the blast is that it takes much less effect upon soft pliable substances, so that if a paper pattern or templet is placed upon a glass surface, the latter will be abraded where the apertures in the pattern expose it, while the paper itself is unaffected.

The propelling medium is usually air, steam being inconvenient for obvious reasons. A pressure of from 5 lb. to 25 lb. per sq. in. is employed, derived from an air compressor, in conjunction with a receiver, which steadies the supply, and provides a reserve. Fig. 9, Plate II., shows a plant, with the compressor on the left, belt-driven, the air receiver at the centre,



and the sand-blast apparatus to the right, with its flexible blast pipe attached. The construction of the apparatus is seen in Fig. 10; the casing contains an upper chamber, A, having a hopper into which the sand is fed, and allowed to pass into a chamber, B, by a valve opening, controlled by a handle. From B the sand is dropped into the last reservoir C, through an opening, controlled similarly by a lever. The air is brought in through the pipe D, passing down into the space below C. On allowing the sand to fall from C through a slot, by opening the valve E, with the handle F, the sand is blown into the pipe G, and thence out of the case into the pipe. The plan view shows an arrangement for two outlets with duplicate valves, so that two operators can be supplied.

When the blast pipe is used thus, it is

necessary to provide a closed chamber for the actual sand-blasting, from which the grains of sand and dust cannot escape. The arrangement glass roof, air inlets at the top, and perforated cast-iron floor plates, through which the dust and sand fall, to be sucked away by the ex-

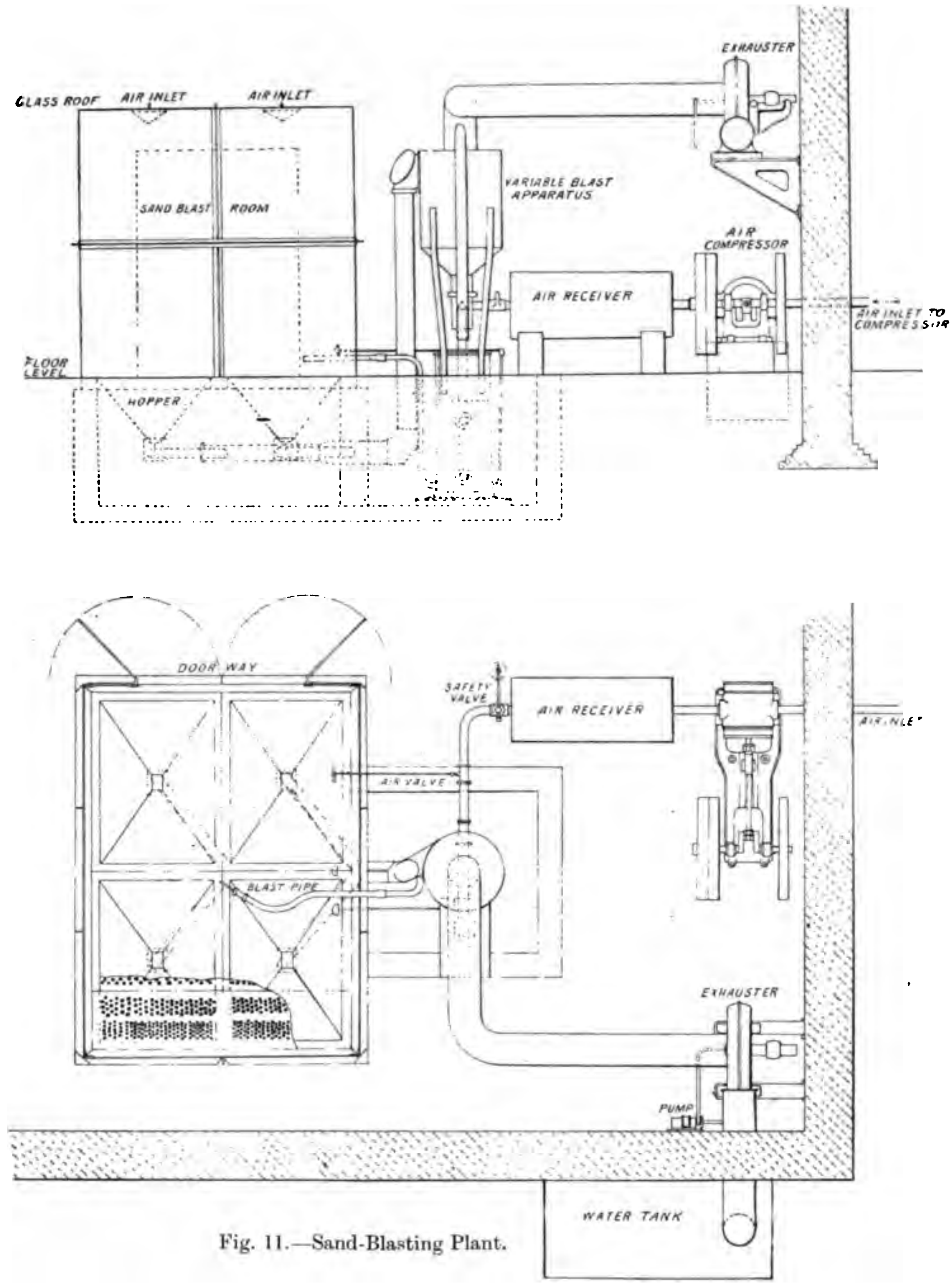


Fig. 11.—Sand-Blasting Plant.

of a complete installation is shown in Fig. 11, and the lettering indicates the various parts. The blast room is built of sheet steel, with a hausting fan, passing through the top of the apparatus, where a cyclone separator and air sieve causes the heavy sand to fall back into

the mixing chamber for use again, while the waste fine dust is carried on and dropped into the water tank. Being then converted into mud it is easily collected and removed. The actual state of mud is reached while in the exhauster, by means of a rose jet, impinging against the blades of the exhauster, and catching the dust as it goes. The sand-blasters wear helmets of leather (one of which is seen on the ground in Fig. 9), into which air is pumped for breathing purposes, the flying sand or shot and dust having no effect upon the operator.

Fig. 12 illustrates a tumbling barrel for cleaning castings and forgings with the sand-blast, blast pipes being arranged inside so that as the barrel slowly revolves, the objects are tumbled over each other, and all portions of their surfaces are in turn exposed to the jets, resulting in a thorough cleaning. The sand and dust escape from the barrel A, through perforations into the box B, and are drawn by the air current along underneath and up into the separator C, where the light dust passes out of the vertical pipe, and the heavy sand drops down again into the apparatus D. As there is a partial vacuum in the barrel A while working, no tendency to leakage outwards exists, and so there is no dust. Fine chilled shot is sometimes employed in place of sand for such purposes as cleaning castings.

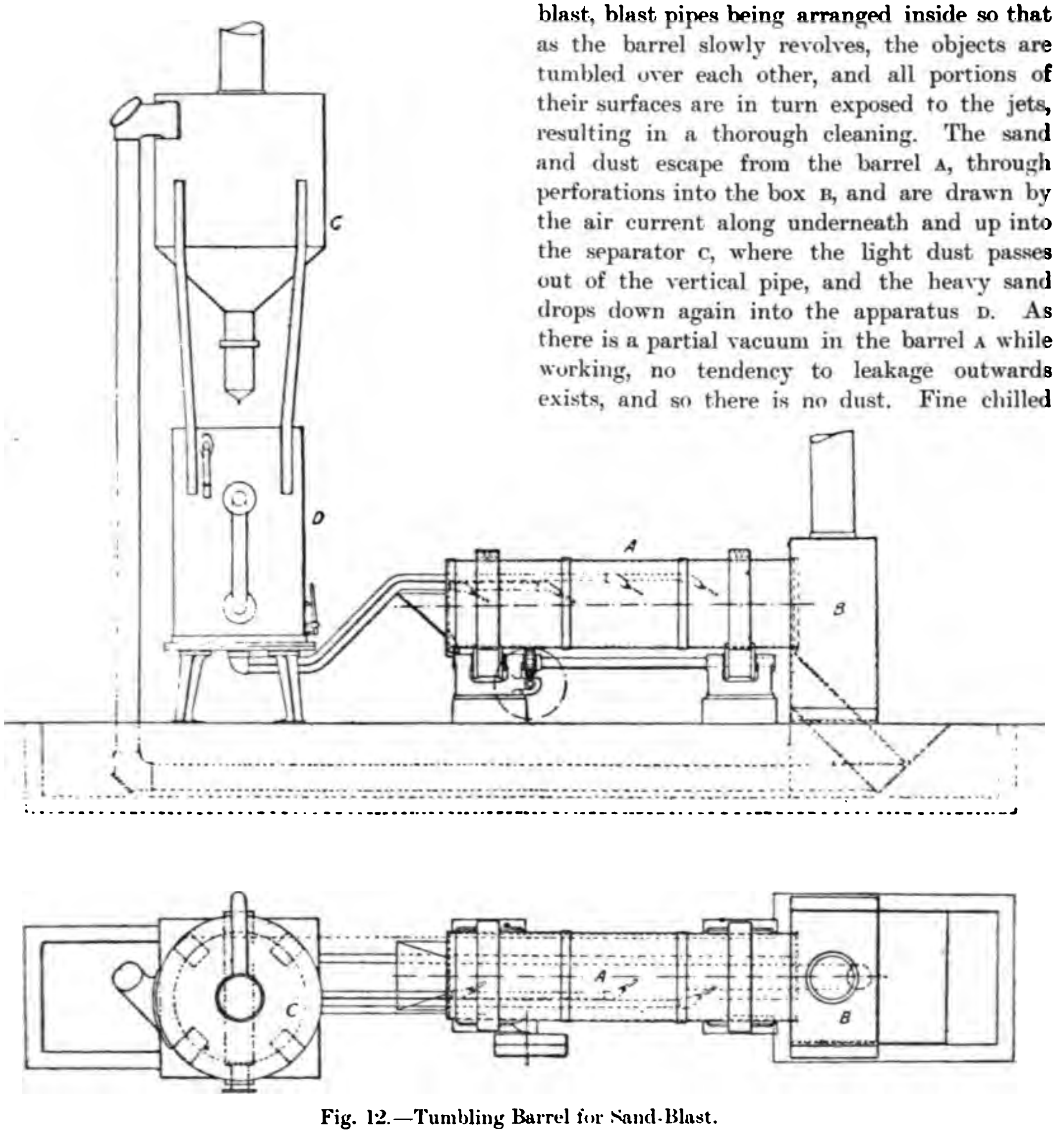


Fig. 12.—Tumbling Barrel for Sand-Blast.

One of the most important applications of the sand-blast is that of file sharpening, both in the case of newly cut files, and for re-sharpening worn ones. In this case water is used, so that the sand is converted into fine

mud (it has been aptly termed a liquid grindstone). Steam is used instead of air for driving the sand jet. Fig. 13, Plate II., shows an apparatus, in which the sand and water mixture is contained in a conical reservoir, seen to the left, and is conveyed to the settling chamber, within which the apparatus is contained, by two rubber tubes. The jet apparatus, shown in enlarged section in Fig. 14, is so constructed that the streams of sand and water are not brought together within the pipe, but at a short distance from the nozzle, so that there is no scouring action tending to wear out

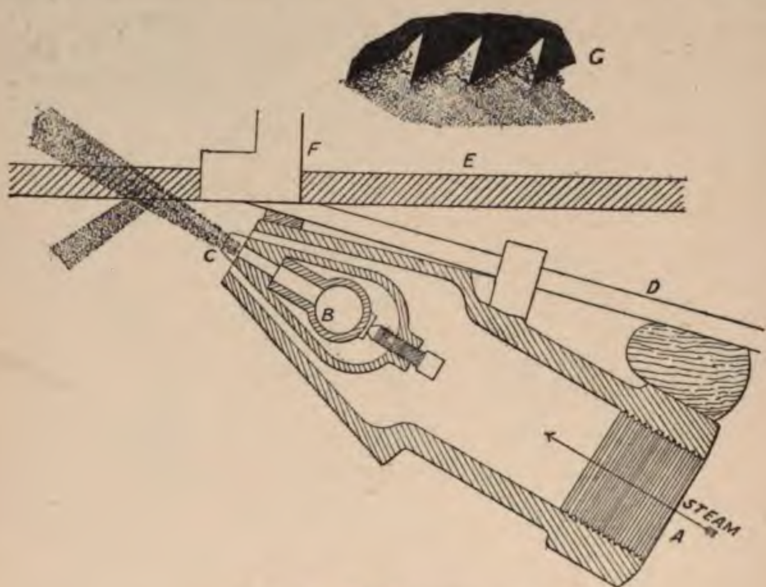


Fig. 14.—File Sharpening Jet.

the pipe. The steam goes in at A, and passing round to either side of the pipe B produces the spray at C. The feeler piece D serves the purpose of a support for the file, and also as a test by which the degree of sharpening can be felt, as the operator moves the file E slowly to and fro. F is a guide which confines the file sideways. G shows the action of the blast on the back of the teeth. The blast is directed at an angle of about 30° with the axis of the file, so that it acts on one side and one edge of the file simultaneously. The tang is held in a long handle for easy control. The steam used is at 60 lb. pressure. The sand should be fine enough to pass through a sieve of 120 meshes to the square inch. This quality may be obtained at plate glass works, where it is a waste product from the grinding, and is therefore obtainable at a low price.

Sand Burnt.—A casting is in this condition when its mould has not been faced, or insufficiently faced. The metal is in too intimate contact with the sand when the amount of coal dust is too small, or when plumbago facings are not used. The result is a roughened surface.

Sand Drier.—A machine used for drying sand before using. It is sometimes done on plates over a core oven, but when large quantities are required a special machine is used. This may be a rotating drum, with spiral ledges, along which the sand is carried to be dropped into a pit, or on to a conveyor. A furnace supplies the necessary heat to the drum, and the draught is under control.

In other forms of drier, a dome shaped furnace is surrounded with the sand receptacle. Or a series of pipes from a furnace are surrounded with the sand space, something like a tubular boiler.

Sand Grinder, or **Loam Mill.**—A machine in which sands, clay, coal, and coke are ground and pulverised previous to mixing and use. Or the same machine may fulfil the functions of both grinding and mixing. A **Ball Mill** in some of its forms is often used. The balls may rotate in a cylinder, or in an annular path. Another is the edge runner, or roller, or mortar mill type in which heavy rollers rotate in an annular path in a pan.

Sanding.—Sand is fed on to the rails in front of locomotive driving wheels to enable them to get a grip on slippery rails. A steam jet is generally used, carrying the sand from

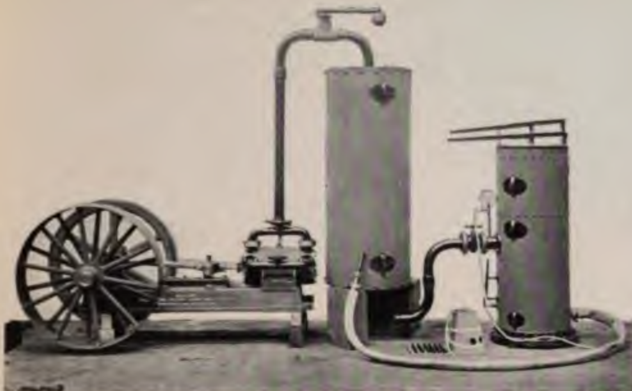


Fig. 9.—Sand-Blast Plant.

Fig. 13.—Sand-Blast Apparatus for Files.

(Tilghman's Patent Sand-Blast Co., Ltd.)

Fig. 15.—Sand Pump Dredger "Coronation." (Vickers, Sons, & Maxim, Ltd.)

To face page 22.

a box, down through the *sand pipe*, which is curved to lay around the wheel and deliver the sand as close as possible to the tread.

Sand Mixing Machines.—After the various foundry sands have been selected in suitable proportions they are mixed. In most small foundries this is done with the shovel, throwing the material about intimately, and promiscuously. But in large foundries machines are often used. They are of horizontal, or vertical types according as the axis of revolution is in one position or the other. The sand passes between two grids, the direction of motion of one being contrary to the other, and the sand is mixed between them.

A rotary machine is the centrifugal type, by Messrs W. Sellers & Co. In this the axis of rotation is vertical. The sand is broken between upright pins on a revolving plate, which is rotated rapidly, throwing the sand among the pins and breaking it up. *See* **Centrifugal Sand-Mixer.**

Sand Pumps.—Dredgers of a certain type designed for excavating in sandy bottoms and soft mud. They are vastly more efficient than grabs for this particular kind of work. The early sand pumps were of crude designs by comparison with later ones. But with perhaps a single exception they all embodied the action of the centrifugal pump, and suction under a vacuum created by the pump.

In the Woodford pump, the pump rested on the ground, and comprised a horizontal disc with two or more arms working in a case. The disc was keyed to a vertical shaft, which was driven by belting or gears from a portable engine. The vertical shaft was enclosed in the discharge pipe.

In Schmidt's pump, the material, consisting of blue sticky mud, was cut up by blades on the bottom face of a revolving disc, driven by a vertical shaft. A centrifugal pump above drew up the sand and water through a vertical pipe, whence it was discharged.

A form of sand pump which has been used in India for excavating from the insides of bridge cylinders when being sunk, is the Kennard, which embodies the principle of the common lift pump. A piston above, a suction pipe below, and a chamber between provided with lift valves are the essentials. When the chamber is full the pump has to be hauled up for its discharge.

In a sand pump dredger the problem is to lift the largest percentage of sand to water, and to discharge as little sand as possible with the water discharged. A dredger, to be efficient, must be able to deal with large quantities of material, and to operate at variable depths. The pump is usually carried in a boat provided with hoppers, in which the sand is carried out to sea and discharged.

Sand pump dredging on a large scale has been carried on successfully in the Mersey since 1890, where five vessels have been employed for the purpose. The latest is the *Coronation*, Fig. 15, Plate II., and Figs. 16 to 18; built in 1903 by Messrs Vickers, Sons, & Maxim, Ltd. She is capable of pumping 4,500 tons of sand per hour, and can carry in her hoppers, 3,500 tons, which are of 70,000 cub. ft. capacity. The vessel, 332 ft. long, is propelled at 10 miles an hour by engines of 2,000 HP. The pumping engines are of 800 HP. The cost of dredging works out to a halfpenny per ton, including repairs, wages, and supplies. The following is a brief account of the operation of the sand pumps.

The sand is pumped by centrifugal pumps with impellers 6 ft. in diameter, and 6 in. wide at the tips of the blades, making about 150 revolutions per minute. The mean vacuum on the pumps at the trials was 8·6 in. There are two similar pumps, each driven by its own independent engine, each delivering sand into the hoppers at the rate of 2,100 tons per hour. The pumps have suction and discharge apertures of 36 in. in diameter, and the suction tubes are of the same size. These tubes project out on each side of the vessel, and each is fitted with a swivel head, around which it can be moved, and raised, or lowered by derricks operated by steam winches on the deck, which are driven by double-cylinder reversing engines. The form of nozzle is important: its shape is the result of much experimenting, having been designed to bury itself in the sand in order to enable it to take up the maximum of sand possible with the least admixture of water. In the original style, in which the nozzle only

traversed the surface, the effect of the suction was to create a hole round the nozzle, which had the effect of increasing the proportion of water drawn up. In the new form shown, Fig. 19, designed by Mr Lyster for work in the Mersey, the grid is at the lowest point of the curve, and the sand is sucked in there. The point becomes buried by the material falling over outside it. As much as 50 per cent. of sand is lifted thus.

The pump discharge goes through a deflecting valve, which either passes it to the *lander troughs*, whence the hoppers are filled, or to a flushing pipe. The landers run alongside the hoppers, and have two discharge valves to each hopper, by which the supply can be regulated. These can be so set that the range of hoppers lengthways of the vessel can be filled equally, the amount of opening being increased in proportion to the distance of the hoppers from the pumps. There are eight hoppers, in two lines of four each. The flushing pipes are arranged within the sides of the hoppers, to wash out any sand remaining after the main discharge. The material is discharged through a valve at the bottom of the hoppers, worked hydraulically, and towards which the sides of the hoppers are sloped. The entire load can be discharged in from five to ten minutes.

Previous to Mr Lyster's improvements, it was found that about 20 per cent. of the sand raised was lost in passing away with the overflow water discharged over the sides of the vessel. This has now been reduced to practically nothing, with also a saving of from 20 to 25

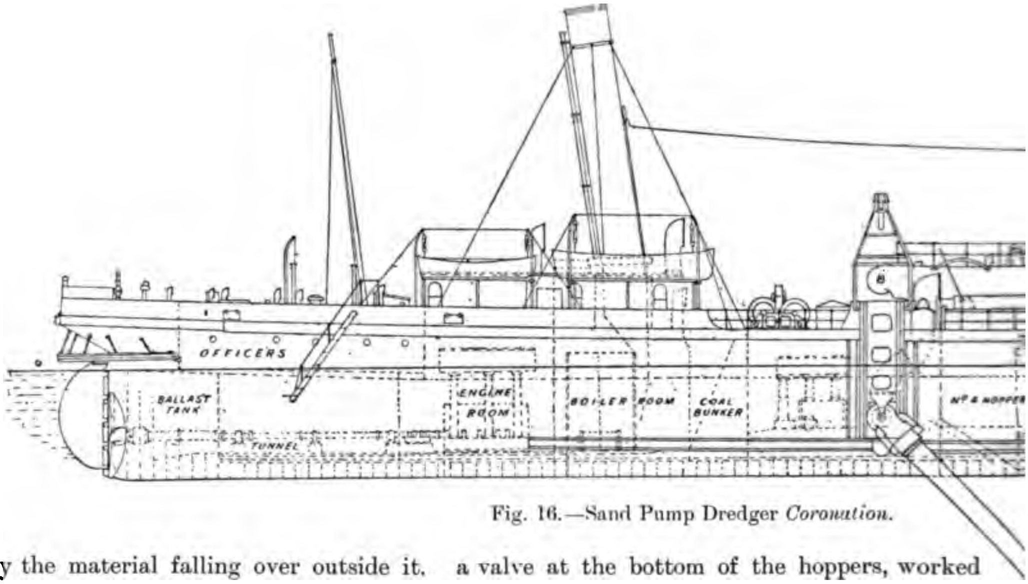


Fig. 16.—Sand Pump Dredger *Coronation.*

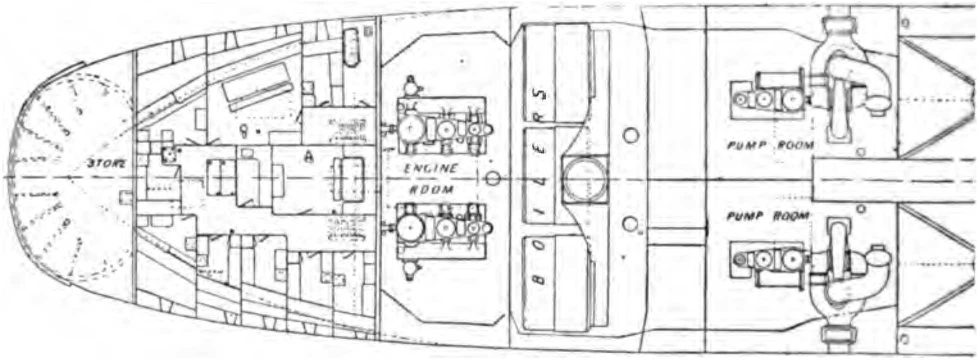
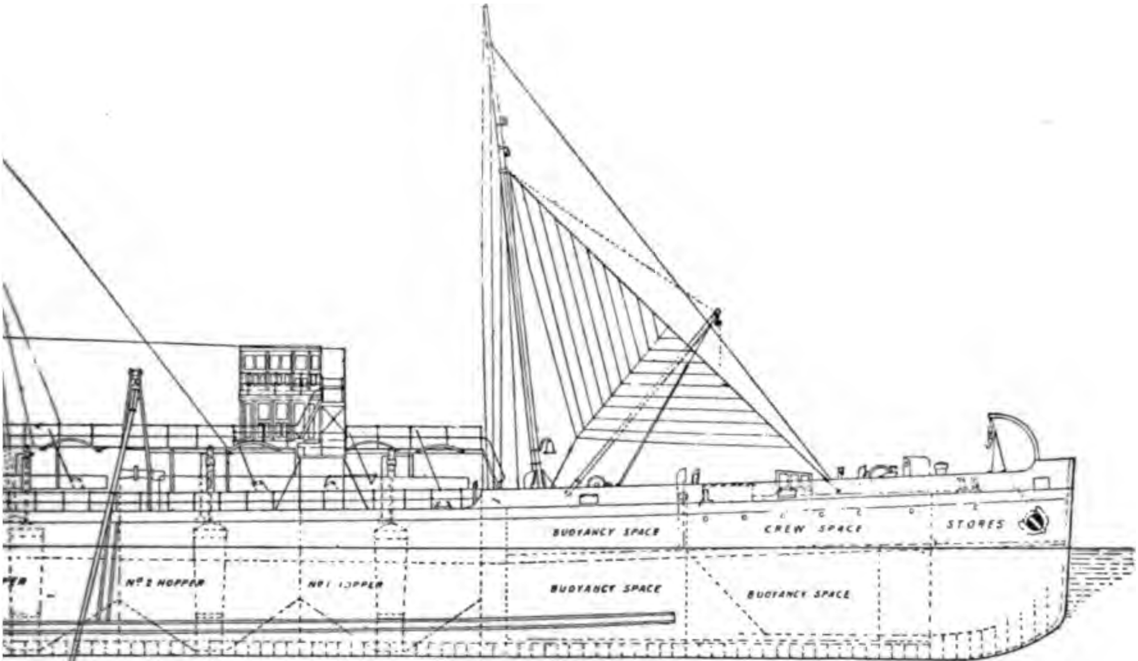


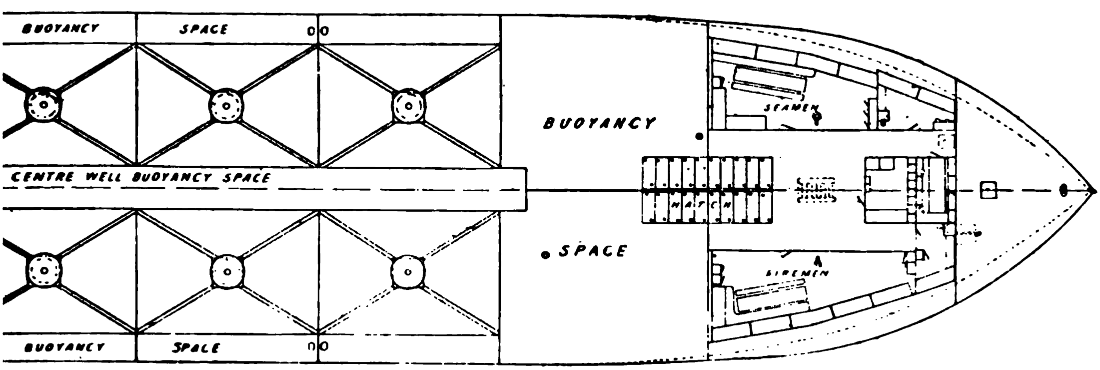
Fig. 17.—Sand Pump Dredger *Coron*



(Longitudinal View.)

per cent. of the time occupied in loading. It is done by covering the hoppers with thin sheet iron, leaving only an opening 4 ft. in width at the centre. A channel or trunk is prolonged above to a height of 4 ft., Fig. 18. The discharge pipes are laid as near to the outside as possible. The effect is, that the water before its discharge has to travel away from the place of discharge, and commotion, and rise 5 ft. up the trunk before it can pass off over the sides. The effect of head is added to that due to vertical rise, and the result is that the solid particles cannot rise with it. Even in a test made of black mud, the percentage of solid overflow was only about half of one per cent.

Sands.—These are used in metallurgical operations for furnace linings, and in foundry moulds for casting into. The sands used for linings have been mentioned under various



over Hoppers and Engines.)

heads. The present article relates to the moulding sands.

Two main essentials must characterise any

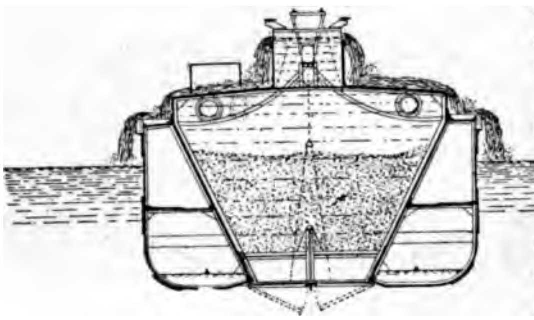


Fig. 18.—Cross Section through Dredger.

sand used for casting into—infusibility, and consistence. A sand cannot be too refractory from the first point of view, but it might

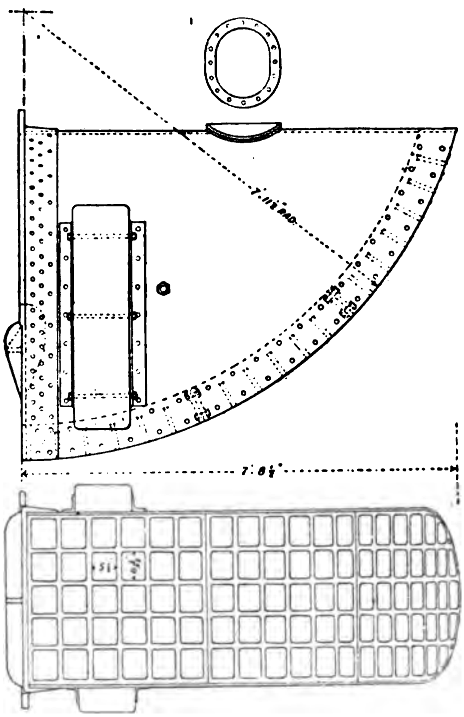
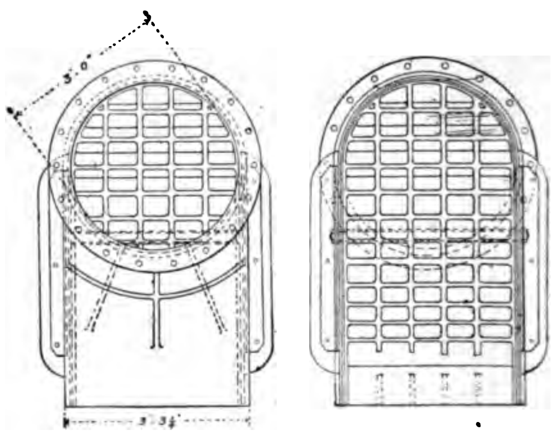


Fig. 19.—Nozzle of Sand Pump Dredger.

contain the infusible element silica in too great proportion for the second. Hence metallic oxides must be present to impart the necessary binding property. Silica is present in proportions which range from 94 to 98 per cent.

A good test of the quality of a sand mixture when tempered with moisture is to squeeze a mass in the hand. If on release it retains the shape imparted, it has sufficient consistency for working.

The moulding sands are found nearly all over the United Kingdom, but certain localities possess better qualities than others. The names of Erith, Falkirk, Mansfield, Worcester, Belfast, are familiar, and there are lesser known sources. Generally, as a matter of economy, firms make use of the sands which lie nearest them. Relatively small quantities of single sands are made use of by comparison with mixtures of two or more kinds, whereby the open or close qualities of simple sands are corrected, and so mixtures are rendered suitable for all the varied classes and grades of work done in foundries.



The New Red Sandstone, and the coal measures yield the principal supplies of moulding sand. Some are found in the Greensand, and in the Chalks.

Mixtures, and Grades of Sand.—So many terms are employed to distinguish these that each had better be explained under its own heading.

Green Sand.—This is a coherent sand, sufficiently so to hold together when moist, and retain the shape left by ramming around the pattern after the pattern has been withdrawn.

It does not denote the sand from any particular locality, but may be any of those just named, some of which are finer, and more open or *self-venting* than others, or mixtures of them. It may be red, yellow, or green, when unused from the quarry. But it must be poured into just as it is rammed, slightly moist, for if dried, the moulds would be friable, and fracture, and fall to pieces. By far the largest number of moulds made are formed in green sand, and mixtures of such sands.

Facing Sand.—The oxidisable elements in the green sand would become burnt on the surface by the contact of the molten metal with them, with the result that the surface of the casting filling up the pitting produced would be very rough. To avoid this, and to produce a clean smooth surface, the body of the sand in the mould is covered by a thickness of from ½ in. to 1 in. of a special mixture of sand containing a considerable proportion of coal dust. The oxidation of the coal dust protects the surface of the metal from coming into intimate contact with the oxidisable elements in the sand. As might be supposed, heavy castings which remain hot longer than light ones require larger proportions of coal dust in the facing sand used. There might be 1 of coal dust to 8 of sand for heavy work, against half the quantity for lighter classes of work.

Dry Sand.—This is also termed a *strong* sand, because it is heavy and clayey, and so bound together with horse manure, or cow hair, or straw that it does not become disintegrated when dried. It also contains coal dust, and frequently a quantity of old used loam, ground up. The moulds are rammed precisely as are those in green sand, the sand being moistened and consolidated by ramming. But it is usually rammed harder, and often vented less, because the sand is largely self-venting due to the burning out of the particles of hay in the process of drying. Drying is done in the core stoves, or in pits.

Core Sand.—This is a dry sand mixture. The same mixture may be used for both purposes. But its composition is varied to suit the mass of the cores. For light cores its composition approximates to that of the weaker sands, being *open*, but having sufficient clay water, or pease meal mixed with it to render it coherent when dried. For heavy work the regular dried sand mixtures are used. What are termed *green sand cores* are not made of core sands, but of the ordinary green mixtures used for moulds. Such cores are not dried, being simply internal portions of their moulds as distinguished from the external, and made by the same methods, often rammed within the pattern itself, instead of in a box. They may be dried on the surface (*skin dried*) just as large green sand moulds often are.

Loam.—This is only distinguished from dry sands in its being used in a plastic condition, in the absence of coal dust, in a larger proportion of clayey materials and of horse manure used, and in the non-employment of the vent wire, with some slight exceptions. It is swept up, and dried thoroughly. There are different grades of loam, coarse, and fine, for roughing up and finishing.

Parting Sand.—This is merely burnt sand which has been oxidised and become non-absorbent. It is produced by heating new sand in the stove, or the sand scraped from the surface of castings in the fettling shed is used. It is dusted on the joints of moulds to separate the sand in different boxes, which without the sand parting would become stuck together.

Black Sand.—This designates the sand which forms the foundry floor, or *floor* sand. It is composed of sand which has been moulded in repeatedly (*old* sand) until most of its virtue has been burnt out. It is employed for filling boxes (*box filling*). Or mixed with a proportion of new sand, it is used for the areas next the pattern, which in turn are covered with a layer of facing sand.

Sand Sifters.—Machines for separating sand of fine grade from the coarser lumps. Hand sifters, as sieves and riddles, are used for the moulds, but these are not understood. Sand sifters are of large dimensions to deal with the sand in quantity, before it is delivered to the moulders.

Sand sifters are of two broad types, the rocking, and the rotary. The majority belong to the first named. Rocking sifters comprise an iron frame suspended from overhead, with a sieve at the bottom on which the sand is

shaken by the to-and-fro movement of the frame, effected by cam teeth. The sand falls into a bin below, and the unbroken lumps pass out at the end, the sifter being sloped for the purpose. In another form the frame is supported from below on four rocking links, and the reciprocation is effected by two eccentrics on a belt-driven spindle at one end. Pneumatic sifters have come into service lately. A rectangular or circular sieve is supported on a tripod. Its rocking links are supported on two of the tripod legs, and a pneumatic cylinder is carried on the apex of the tripod, and oscillates the sifter rapidly.

In many small foundries the common riddles or sieves are used, being reciprocated by hand on two horizontal bars of an iron-framed horse, the sand falling below. What is termed *screening* is allied to sifting, being a preliminary to it or alternative thereto. A large rectangular riddle is supported at an angle of about 30° or 40°, and the sand is thrown against it with a shovel. The finer sand passes through, and forms a heap behind, the coarse lumps tumble down in front. Another common form has the riddle rocked to and fro by means of cranks attached to the frames, and operated by vertical shafts. These are actuated by bevel wheels from an upper horizontal shaft, which is driven by a pitch chain from a hand-wheel. The machine is carried on a four-legged framing.

Rotary Sifters.—In one type of these the riddle is of hexagonal drum shape, revolved on a horizontal axis by belt power. The lumps of sand are partly broken by horizontal bars passing through the interior. A steel brush striking against the sides of the drum prevents the meshes of the screen from becoming clogged with sand. The lumps are prevented from falling out and mixing with the sand by an internal projecting rim.

Sandwich System.—An attempt made to combine the advantages of shop training and technical study. It has been adopted in connection with several technical schools and colleges, students spending a winter term in the college and the summer months in the shops. In another way it has been carried out by individual firms, apprentices spending a certain number of hours weekly in the training school instead of in the shops, the period spent in school tuition being counted as working hours.

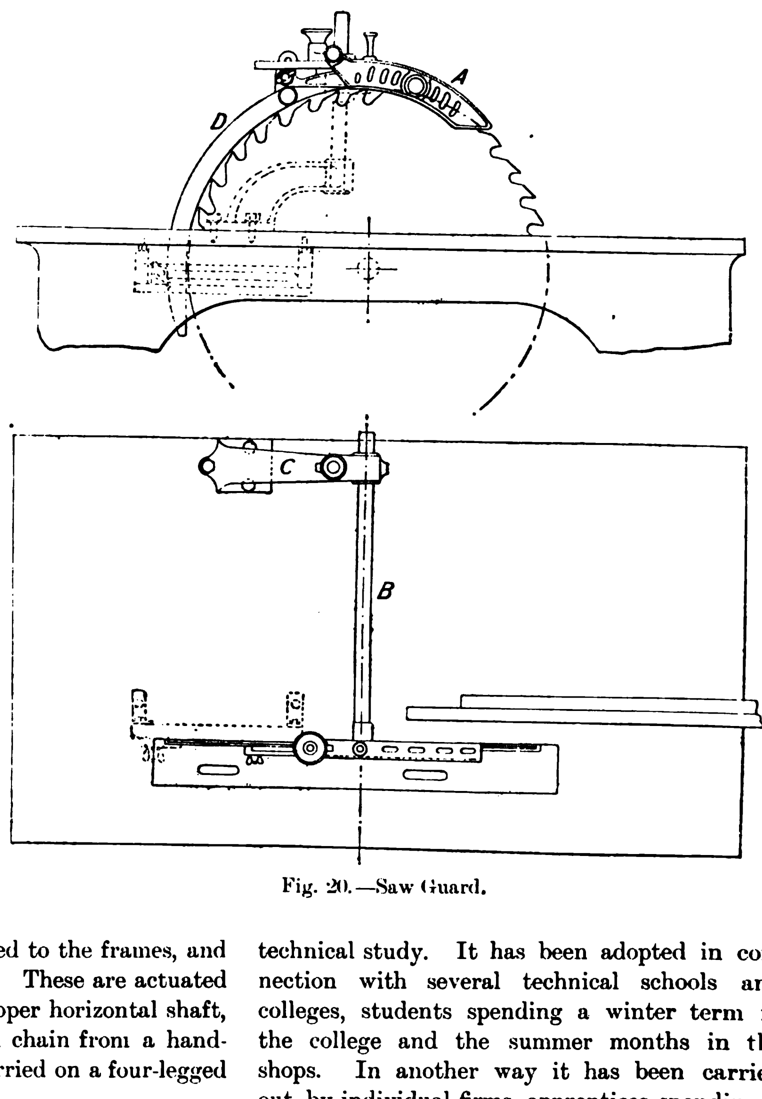


Fig. 20.—Saw Guard.

system promises well by comparison with earlier practice of separating college and training by intervals of several years.

ıw Fence.—A plate which controls and ›s timber in a straight line past a circular, ınd saw. It is capable of adjustment to differing thicknesses to be cut, and has a plate attached, which is moved forward ıckward to suit the diameter of saw in An angular or tilting adjustment is in-›d, when bevel sawing has to be done. y benches have the fence held by an arm bar at the end, so that the entire fence be swung down out of the way, leaving whole surface of the bench clear for cross-ng purposes. Some fences have a set of ›s let into the face, when self-acting feeds employed, as in the rope, and roller feed ines.

ıw Guards.—These are necessary on lar saws to prevent the sawyer's hands caught through an accidental slip. A guard should be adjustable, and it should letely protect and enclose the teeth at all . Messrs M. Glover & Co. have a type ard which is largely used; it is shown in 20. The hood A, of brass, is hinged to a ıg block which is fixed by turning a small -wheel. The whole guard is supported by , B, standing laterally exactly above the saw lle, and vertically adjustable by a bar set in mping bracket, C, attached to the machine . A therefore may be brought down close ıe stuff being sawn, no matter what its ness may be within the limits, so that the dant cannot catch his fingers when feed- A riving knife, D, guards the back of the and is provided with means of adjustment ifferent diameters.

ıws.—Sawing machines are treated under al specific heads. We here deal with the tself as a tool, and its efficiency or other-

eth.—Saw teeth differ in shape and size ding to the kind of work, and character of ood for which they are intended. Gener- hey are formed to cut only in one direc- of the saw's travel, and they either have ıtinuous movement in that direction, as band and circular saws, or do not cut on the return stroke. The chief exception to this is the large two-handled cross-cut which is operated by two men, and cuts both ways. Teeth that cut equally well in both directions are slower in their work, and, with the exception just mentioned, give more trouble in holding the wood securely, and exerting equal power each way. Teeth intended to cut in one direction only have their points inclined in that direction, that is, if centre lines were dropped from the points perpendicular to the line of teeth, the teeth would not be symmetrical on each side of the centre line as they are in a cross-cut saw, but the greater portion of each tooth, and in many cases all of it, would be behind the line dropped from the point. This inclination is called *rake*, or *hook*, and is greatest in saws for ripping softwood, and least in saws for cross-cutting hardwood. It is much greater in machine saws than in those worked by hand.

The shapes and angles of saw teeth are therefore governed by the relative hardness, or softness of the timber which they have to cut, and whether ripping, or cross-cutting are done. The outlines may be absolutely angular, with no curves, or the latter may be introduced freely. To take typical teeth for hand saws, Fig. 21, the difference between the form for ripping, A, and that for cross-cutting, B, may be observed; the front of the teeth in A lies at right angles to the line of teeth, the back slope making 30° thereto; in B the same cutting angle is preserved, but it is thrown round, so that the tooth front has negative rake. The teeth are also pitched finer for cross-cutting than for ripping; this applies to other classes of saws. All the smaller saws used for benchwork have teeth of the same shape as these, with the same amount of rake. The points of the teeth do not overhang the roots, but the latter are slightly in advance in the direction of the line of teeth. With more rake, the teeth would catch instead of cutting through the wood easily, and with less they would not cut as rapidly. Plain angular shapes of teeth used in band saws are shown at C, with or without a slight rounding at the root. The pitching may be very wide, D; greater strength is secured by ample curving, E, with slight flattening behind the point, or complete curves,

F. The teeth of saws used in frame-saw machines are usually like G, rather long, and with a little front rake.

Cross-Cuts.—The large hand cross-cut saws are noticeable chiefly for the special forms of teeth which are used, beyond the plain peg tooth, H; the M-teeth, J, are common, and also noted on many cross-cuts is that a few peg teeth of fine pitch are placed at one end, in the case of a single-man saw, and both ends in a two-man saw, to enable a start to be easily effected in the timber, L. What are termed *cleaner* teeth are introduced in many patterns, to produce better work; thus at M, teeth *a*

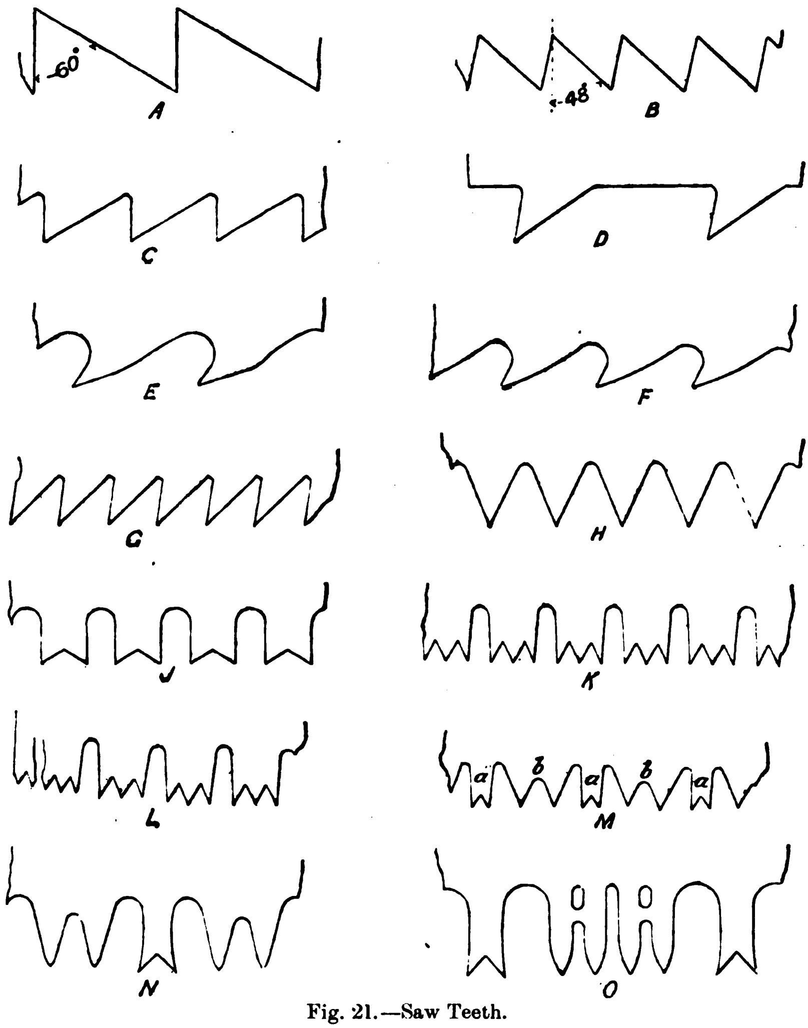


Fig. 21.—Saw Teeth.

a similar construction, K. The middle teeth in K and L are termed *regulating* teeth, because they admit of altering the extent of the cut, according to the strength of the sawyers. By putting more bevel on the centre teeth, the saw will cut with more avidity; if on the other hand the teeth are filed obtusely, the saw will penetrate less freely. A point that may be perform this function, their points being set slightly below the level of the other teeth *b*; N and O represent other shapes of teeth, and numerous makers have variations based on these, some more or less fanciful in outline. Saws for stone and for ice have very long and finely pointed teeth.

Circular Saws.—Circular saw teeth are very

diverse in form; angular shapes, shown in Fig. 22, A, and B, used for ripping, and occasional cross-cutting, giving place to more obtuse angles, C and D, for harder woods. E gives a stronger backing to the tooth. The usual English form of tooth for pine and deal is that at F; more hooked shapes are also common, cutting well, though rather more delicate. This is shown at G; Messrs Disston make gullet-tooth saws in which the edge behind the point forms a portion

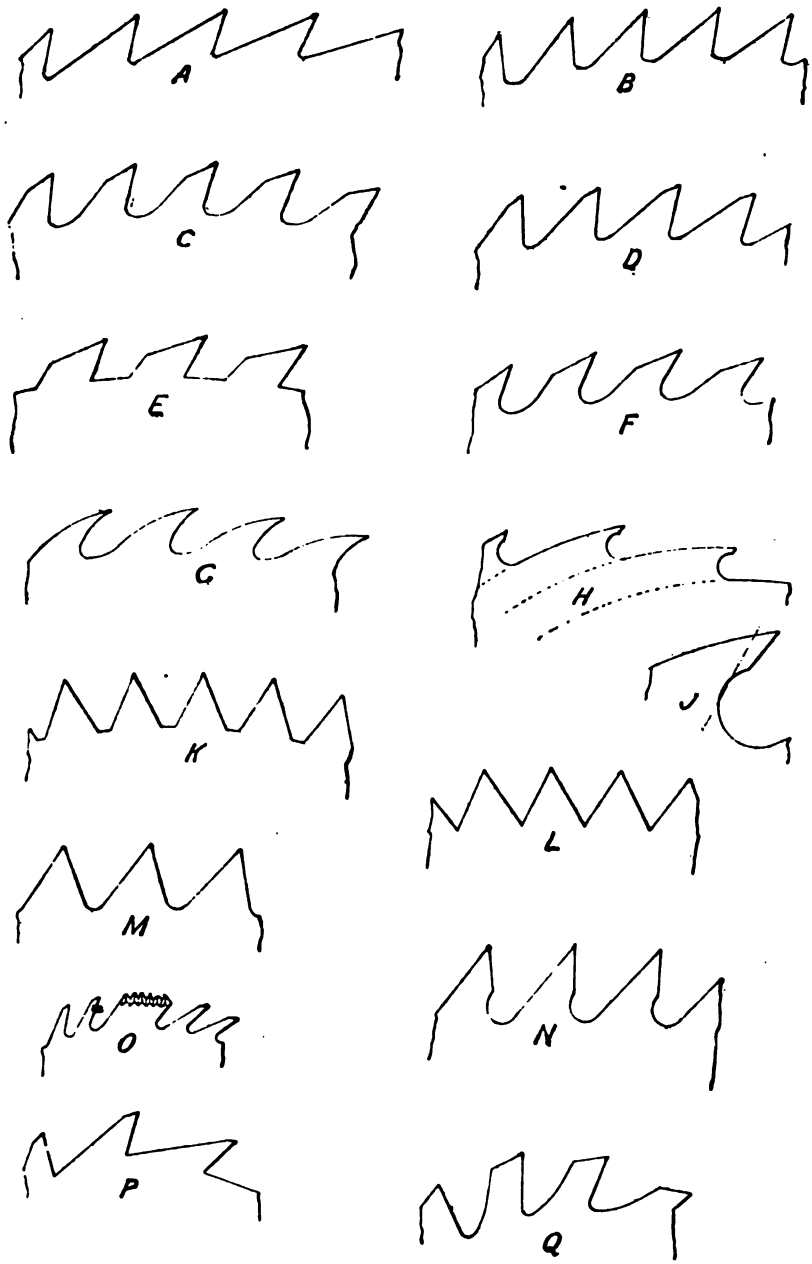


Fig. 22.—Teeth of Circular Saws.

of a regular spiral, leaving a good space for dust clearance. The undercutting, seen in the enlarged view J, enables sharpening to be done by simply filing the front of the tooth; the gullets are chambered out, or *gummed*, as soon as repeated sharpenings have brought the face flush with the gullet bottom.

Cross-cut saws generally have the peg tooth K, or the fleam L. A slight amount of forward inclination is sometimes imparted, M; if the teeth are undercut, as at N, the labour of sharpening will be lessened. Mitre saws, used for fine work, have *cleaner* teeth interspaced as at O;

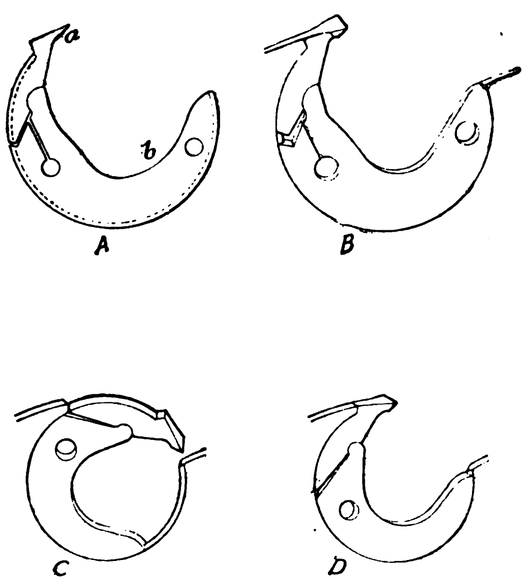


Fig. 23.—Inserted Teeth.

grooving saws, which are thick, and hollow ground, have teeth similar to P, or to Q.

Inserted Teeth.—The inserted-tooth circular saws, which have been developed largely in America, are made with detachable teeth or points inserted in recesses around the rim. The advantages are that the full diameter of the blade is always retained, and that in case of damage being caused, nothing worse than breakage of a few points, or their ripping out can occur, so that it is not necessary to cut the saw down sufficiently to form a new circle of teeth. The points are also easy to sharpen, and they cut freely. The method of holding each point, or bit, *a*, is by a shank, *b*, see Fig. 23, A, the Hoe type, both of these fitting by vee grooves against the vee'd edges of the socket; the heel of the bit backs against a shoulder which takes the thrust, and the tight fit of the shank, combined with its springiness, holds the two firmly in position. A special wrench with pins fitting the holes in the shank is used for the insertion and removal. The sharp chisel point may be noticed. The bit and shank are shown in place at B. The Disston method is illustrated at C and D; in some cases pins or rivets are used to retain the points in place.

Metal Cutting Teeth.—Saws for cutting metal are made with teeth having no front rake, or only a little. Hack-saw teeth are similar in shape to band-saw teeth for metal. Circular saws have the front faces of the teeth radial, like milling cutters. Backing-off, as in milling cutters, is often done to provide clearance. Inserted teeth of high-speed steel are much used for heavy sawing, including armour plates. The teeth are held in by wedges, or screws, or a combination of both.

Tension.—Reference was made under **Band Saw** to the hammering or tensioning of those saws. In circular saws a different set of conditions prevails; owing to the tremendous speed at the rim, that portion tends to expand and stretch, and so run untrue, which results in bad sawing, on account of the teeth dodging knots, and shakes. By hammering or blocking the blade around the central area it is loosened there, and so compensates for the expansion of the rim. The higher the speed of the saw, the greater the looseness necessary, and so it follows that a tension imparted to a given saw will not suit it if run at higher or lower speeds, or if the diameter is reduced. Trouble from this cause is overcome to some extent by packing the sides of the saw, so that it will become heated at the parts required by running against the packing. Thus a saw slack at the teeth and tight at the centre would be packed tightly close to the centre. Packing near the teeth is required as a guide in large saws, but the amount of heat generated depends on how tightly the saw is packed. The inserted-tooth saws always remain of the same diameter, and do

not need re-tensioning, like solid saws that have been reduced.

Saw hammering is a difficult operation, requiring long practice to enable one to become proficient. This is work that should be done by an experienced man, and saws are generally returned to the makers for the purpose. The tools employed are an anvil of oblong form, a couple of straightedges and two hammers, one round-faced, the other with flat cross-panes. Before any attempt is made to tension the saw, it may be necessary to obliterate bumps, or lumps on the plate, which interfere with its proper running; these lumps are tested by applying a straightedge, and are then removed by placing the saw on a block of wood, and lightly hammering on the convex side of the lumps with the round-faced hammer. To examine the tension, the saw is supported horizontally with one edge resting upon the anvil, and a straightedge is applied across the face. If the saw has lost its tension the plate will touch the straightedge all across; properly the central portions should hang sufficiently loose to enable light to be seen under the straightedge, from rim to rim. The amount of clearance requisite is a matter for judgment and experience. The looseness is increased by spreading the metal with numerous blows of the round-faced hammer, as the plate lies flat on the anvil, treating both sides, and working fairly close to the centre and to the rim. Care should be taken not to unduly hammer any places where local looseness is excessive, as evidenced by applying a short straightedge from the centre out to the rim, and observing the light beneath. Should the centre of a saw be too loose, it is corrected by hammering around near to the rim.

Manufacture of Circular Saws.—This is a large industry which has grown much by the employment of the hot and cold metal cutting saws.

The saws are made from ingots of a suitable grade of steel, reduced to thickness in rolls. A plate is sheared to the circular outline, and the central hole drilled. The teeth are formed by punching, and the burrs thus produced removed by grinding. Tempering follows. Heating is done in a furnace to a bright red, and hardening in a bath of sperm oil. Temper is given by burning off the oil. As the blade has become warped it is hammered on an anvil, followed by grinding. This is done between two grindstones which revolve in opposite directions, the blade of the saw being set vertically. Polishing with emery follows. After this the hammering is imparted, the object of which is to give the proper tension to the blade to allow for expansion when working. Setting and sharpening follow.

Saw Sharpening.—The points and cutting edges of saw teeth soon become dull with use, and require frequent sharpening to get the best results from the saw. The set of the teeth also diminishes with wear, and after the saw has been sharpened a few times it requires re-setting. The latter operation is generally performed first, so that the freshly sharpened edges shall not be dulled by subsequent setting.

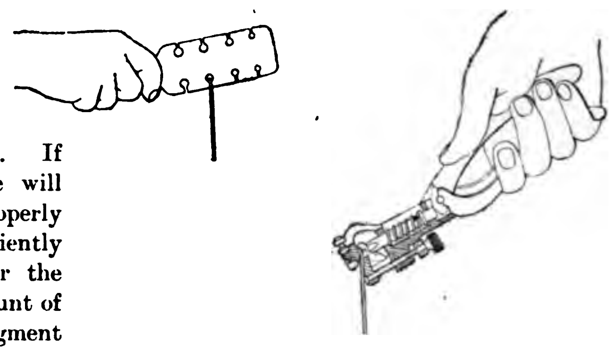


Fig. 24.—Setting Saw Teeth.

The *set* of a saw is the amount to which the teeth are bent alternately to each side, so that they will make a cut slightly wider than the thickness of the blade, thus enabling the latter to follow and clear itself without excessive friction. More set is necessary for cutting across grain, especially in soft wet wood, than for ripping with the grain. The ordinary hand saw requires a great deal of set, compared with most other saws. There are various methods of imparting this. One of the simplest is to bend the teeth with a plain hand set, as in Fig. 24. This is sometimes fitted with a guide to ensure bending each tooth to a uniform amount. Alternate teeth are first bent to one side, and then the saw turned

round and the others bent to the other side. Another simple way is to lay the saw on a block with its teeth to one edge, and set them by tapping with the pene of a hammer. This also, of course, requires considerable skill to obtain uniform results. An improvement on these methods is to use a set of the kind shown in Fig. 24. Here the squeezing of the handles together acts powerfully on a punch which is pushed forward and bends the tooth to an exact amount, governed by the extent of the setting of the jaws. There are also varieties of sets in which the saw is laid flat, and a vertical punch is tapped by a hammer, the amount of set being regulated in various ways. It is important in all cases that the teeth should be set uniformly, and the amount should not be more than is necessary for the work which the saw has to do, or extra force and time

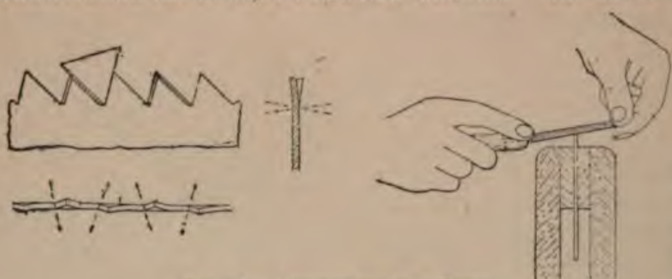


Fig. 25.—Sharpening Saw Teeth.

will be required to make the needlessly wide cut through the wood.

Swaged teeth are those in which the front face of each tooth is swaged or jumped up, so broadening it sufficiently to afford the necessary clearance. This is an alternative to the setting of teeth to right and left, and is practised largely in America. The swaging is performed by forcing a hardened steel die against the tooth face suddenly, the die being operated by a lever. A roller is sometimes employed, rolling along and spreading out the metal.

The teeth points of a saw should all be of similar height, and this is ensured before commencing to sharpen by running a flat file several times down the saw on the points, thus reducing any that stand above the rest. To sharpen the saw, it is put in a vice, teeth upwards, and the file used as in Fig. 25. A file of triangular section fits the teeth of ordinary bench saws, the teeth of which are shown in Fig. 21, A, B. The file beds down completely to the bottom of the tooth spaces, and the material is removed chiefly from the backs of the teeth. Generally, two or three strokes of the file are necessary to bring each tooth point to a keen edge, but the filing must be carried equally right to the roots of the teeth, or they will become shallower. The file is tilted, so that the transverse angles will about correspond with the dotted lines in Fig. 25. Differences in rake of teeth do not require any difference in the file, but only in the amount to which it is tilted, for the spaces of this class of teeth always form an angle of 60°. The teeth not being filed square across, but to alternating angles, results in a series of acute edges and tooth points, standing out slightly to each side of the saw when the teeth are set or bent over alternately to each side, as shown. For soft wood the angles should be more acute than for hard. The teeth are done in alternate order so that the file can be held at one angle all the time along one set. The backs of those teeth which lean away are filed, and then the saw is turned round in the vice and the others done. The eye and hand alone are relied on to keep the angles correct and uniform, but it is not difficult to follow the existing angles on the teeth. Teeth with gulleted roots are generally sharpened by a machine, but when filed by hand, files of suitable shape are required for deepening the gullets. This is not always done every time the points are filed.

Saw Sharpening Machines.—These have come into general use in recent years, taking the place of hand sharpening. The earlier attempts dealt chiefly with band saws, using a file automatically reciprocated by the machine, the saw being fed forward to the length of a tooth between each reciprocation. The gulleting machines for deepening the tooth spaces in circular saws with emery wheels came into use, leaving the sharpening still to be done by hand. At present emery wheels are used for band and frame saws, and for sharpening as well as gulleting circulars. The saw is fixed,

and the different bevels of the front and back of its teeth are imparted by the movements of the emery wheel itself. Not only is the work done with perfect accuracy, but the output is several times greater than that produced by hand.

A fully automatic saw sharpener by Friedrich Schmaltz of Offenbach-on-Main, is shown in Fig. 26. The required automatic movements are three in number; one of feeding, to carry each tooth along, an up-and-down motion of the grinding wheel, and a swivelling movement of the same, to impart the bevel to the teeth. All these must be capable of variation to suit different saws. The wheel A has its spindle bearings in a swivelling frame, B, clamped at any required angle by tightening a nut, *a*. A special arrangement of pulleys is necessary to accommodate the angular movements of the spindle; the self-contained countershaft C affords two speeds to a pulley, D, on a shaft driving a smaller pulley, E. The latter actuates another belt passing round idlers to a long vertical drum, F, and thence another belt conveys the motion to a pulley, G, on the end of B. A belt from this, going over idlers, turns the grinding spindle.

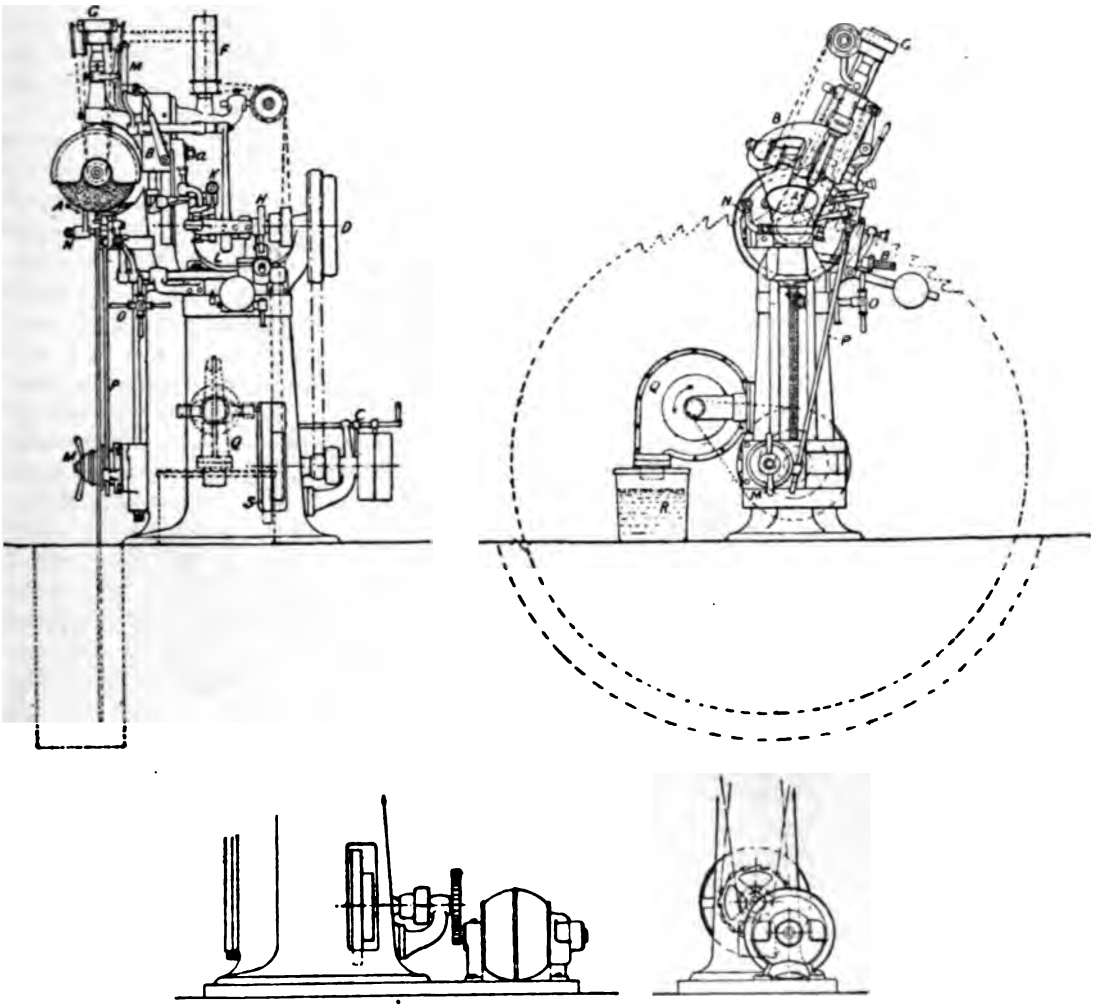


Fig. 26.—Saw Sharpening Machine.

The feeding motion is derived from an

eccentric, H, on the shaft of D, moving a lever which rocks a horizontal shaft moving the spacing pawl J; the amount of movement is adjustable by turning a screw, *b*. Another eccentric, K, operates the up-and-down motion of the slide B, through an arrangement of pivoted levers reciprocating a rod attached to the bottom of B. The stroke of this mechanism is also adjustable by a screw. The third, or swivelling motion of the head takes place through an eccentric L, rocking a series of levers ending in one sliding on a rod at the back of B, thus turning the wheel partly round, and then back again, by means of the socket with which it is carried in B.

Circular saws are held by their centre holes upon an arbor carried in a slide, M, which has a lateral adjustment for the purpose of getting the front faces of the teeth properly into line with the wheel. A guide, N, is set to lightly press against the saw blade and keep it in position laterally. M is adjustable vertically by a screw and handle, O, to accommodate various lying to right and left, at a suitable distance to keep the blade taut. Frame saws are gripped by each end in a couple of vice jaws forming part of a frame sliding on a bar below the wheel.

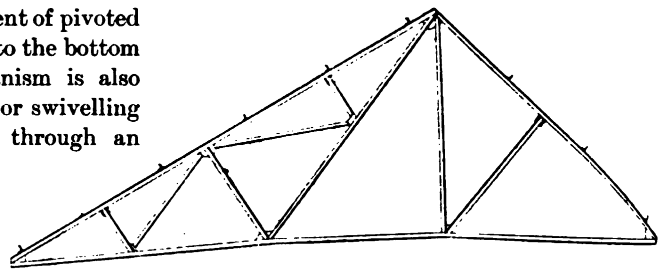


Fig. 27.—Saw Tooth Roof.

The action of the wheel in grinding teeth is such that after descending into the root, it begins to rise, slightly grinding the back of the adjacent tooth, then rising clear; the saw is then fed one space, and the wheel coming down again, grinds the next tooth face, and so on.

Saw Tooth Roof.—An old design, long used in weaving sheds, but which has been

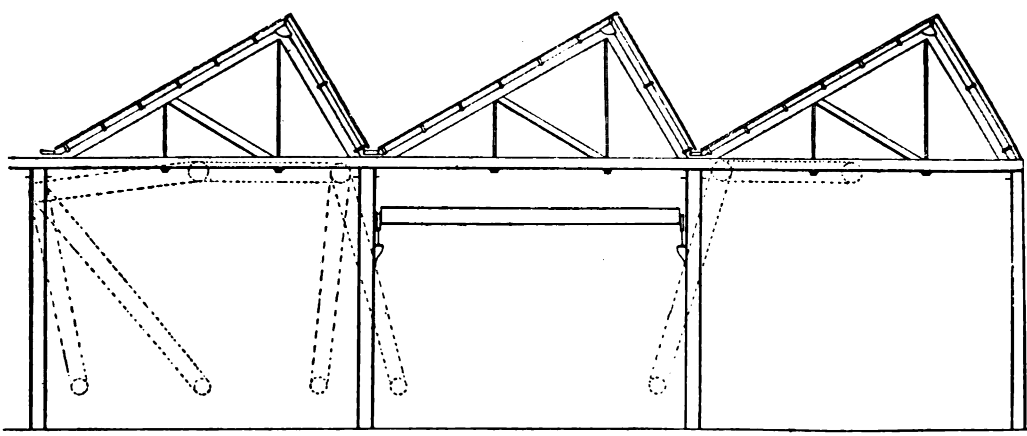


Fig. 28.—Saw Tooth Roof.

diameters of saws, and there is a radius rod, P, to make the pawl J work in a curve of the proper radius. The exhaust fan Q sucks the flying dust from behind the saw, through a mouth there, down and out into a water tank, R. The fan is driven by a belt from the pulley S, on the shaft of C.

Band saws are passed through a flat guide below the wheel, and are supported on wheels largely adopted in recent years for engineers' factories. It derives its name from its dentated unsymmetric form, and its advantage is that while giving ample light, it prevents the glare of direct sunlight coming into the shop, the glazing always being on the north side of the roof. It is necessary to lay out the roofs approximately due east and west. Hence the saw tooth sometimes runs across the shops,

ies longitudinally. The design is largely in American shops. Views are roofs in section in Figs. 27 and 28.

ſold—Scaffolding.—An accumulation y solidified iron in a cupola, due to bad g of coke and iron. The iron blocks up la, and interferes with the free melting, y disable the furnace. In that case it be chipped out, generally with much to the lining. Sometimes termed

e.—*See* **Boiler Explosions**.

ing.—Removing incrustation from boiler y chipping with the scaling hammer, h chisels. It must be done with great ; the surfaces of plates, and rivet heads ecome nicked and indented.

ing Hammer.—A chisel-ended ham- *ee* **Hammers**.

tling.—Denotes the sectional dimen- f materials, whether timber, iron, or

enging, Scavenging Charge.—A adopted in gas engines to prevent pre- when gases of high calorific value, to a large compression, are dealt with. sts in opening the air valve before the valve is closed, so that a current of air through the cylinder sweeps out the s of combustion that remain.

ng as gas engines were of small size, king under low compression, say up to the scavenging device served its pur- But it has no place in the larger engines gh compressions now made to utilise nace and producer gases. The residual e too small to be taken account of, and ion does not occur. A scavenging nent would add much to the expense e modern engine.

le's Curve.—Also termed the *Tractrix*, *ory curve*. The name Schiele is applied, he invented an instrument for describing is an antifriction pivot, designed to qual wear between the pivot and its ll points. An ordinary conical-ended es not wear equally. In this the wear ith the product of the pressure into the and the latter varies with the radius. iele pivot is designed so that the wear vertically will be alike everywhere. To ensure this, the lengths of the tangents to any points of the curve from the curve to the axis are alike. This shows how to obtain such curves. Divide (Fig. 29) the vertical line representing the axis into any number of equal parts, and draw a horizontal at one end at right angles. Set off a point equal to the radius of the pivot, and draw lines from each point of division to this point. These represent tangents. Measure off the length of the horizontal on every line from each point of division, and draw a curve

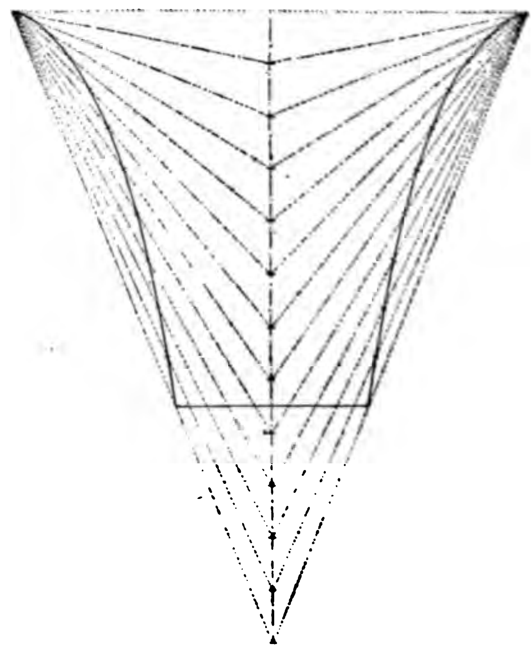


Fig. 29.—Schiele's Pivot.

through these intersections, giving the curve required.

Though this is a theoretically perfect bearing it is seldom made in practice, because being too troublesome to fit. A close approximation is made thereto by means of flat profiles, which are easily tooled. For an example, *see* **Boring Mill**.

Scotch Boiler.—The ordinary cylindrical return-tube boiler, used for marine service, which displaced the rectangular or box boiler when pressures began to exceed 25 lb. and 30 lb. It owes its value to its greater strength, and to

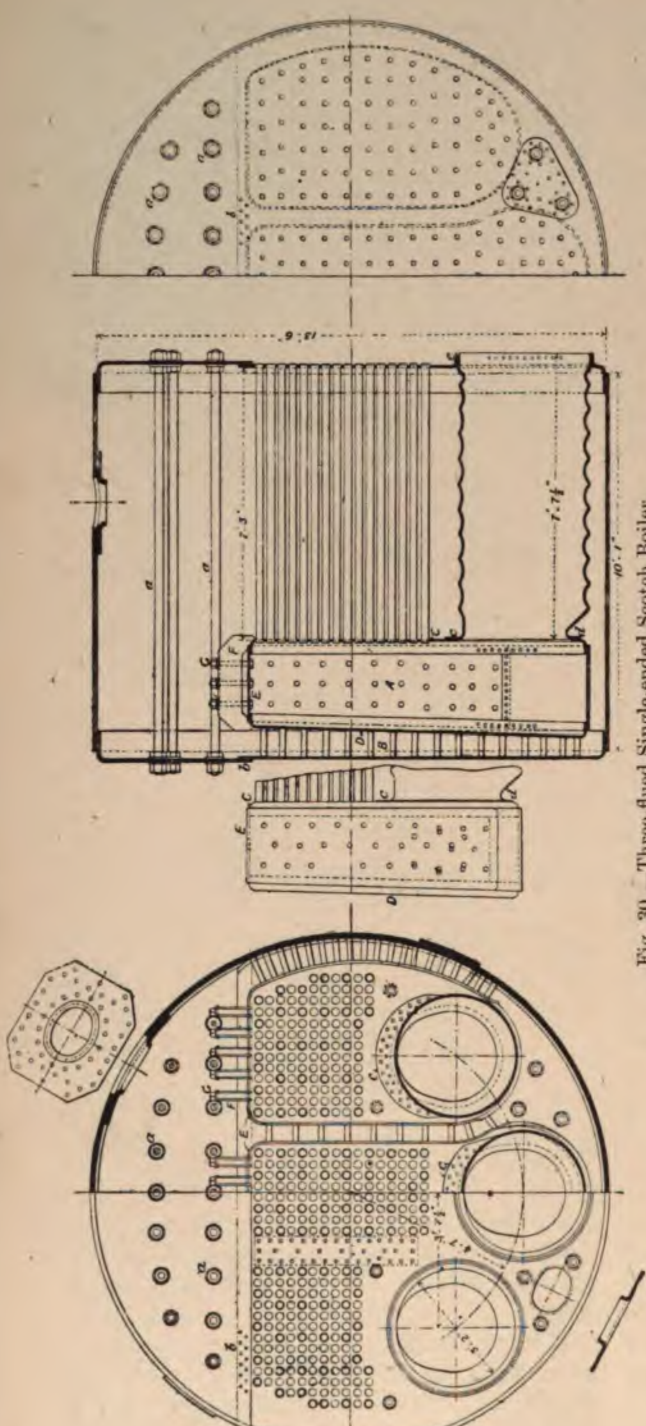


Fig. 30.—Three-flued Single-ended Scotch Boiler.

a lessening of the number of stays required. No vertical stays are wanted, but only those for the flat ends, and the combustion chambers

The boilers are divisible into two main types; the *single*, and the *double-ended*, signifying those which are fired from one end only, or from both ends. The latter may be regarded as single boilers, set back to back. The difficulty in single-ended boilers is to get sufficient length of grate for heating surface. The number of furnaces is limited, just as in Lancashire boilers. They range from one to four, three being a usual number. The minimum furnace diameter is about 36 in., the maximum about 48 in. One furnace may be used in shells to 9 ft. diameter, two to 13 ft. 6 in., three to 15 ft.

The *combustion chambers* are the spaces beyond the furnaces in which the furnaces terminate, and which are extended upwards to receive the ends of the smoke tubes, which return thence through the water space to the smoke box, attached to the front of the boiler. Each furnace usually has its own single combustion chamber, though in some instances a single chamber is common to two furnaces. The objection to this arrangement is that in the event of a tube bursting, both furnaces would be thrown out of service. An advantage is that stoking in the two furnaces can be done alternately, and the steam supply well regulated.

Double-ended boilers may have a combustion chamber common to the furnaces at both ends. Or all the furnaces at one end may have their own common combustion chamber, separated from the other by a water space. Or each furnace may have its own chamber. Each of these designs is common.

Oval boilers are used when the width available is limited. Their section is that of two half circles, joined by flat sides. They are made both single, and double ended.

The Scotch boiler involves the heaviest work in boiler making, due to its large

dimensions. Pressures now often exceed 200 lb. per square in., involving plates $1\frac{1}{2}$ in. thick. The same difficulties have been met with and surmounted in the furnaces as in the Lancashire type, the old plain tubes having been superseded by short lengths with flanged seams, and by corrugated and ribbed types, *see* **Furnace Flues**. The employment of steel in place of iron has done much for the development of the Scotch boiler, without which the boilers of the present steaming capacity and pressure would not have been practicable.

A large Scotch boiler by Messrs Vickers, Sons, & Maxim, Ltd., is shown by Fig. 30. Its shell measures 13 ft. 6 in. diameter, by 10 ft. 1 in. long, and is built of $1\frac{1}{4}$-in. steel plate. There are three furnaces of Morison's suspension type, measuring 3 ft. 2 in. inside the corrugations. In these large boilers, one of the great advantages of steel over iron is apparent. Though the shell is so large, it is built of two plates only, united with butt straps. The end plates are also each formed in two pieces only, united with seams, the riveting for these being shown at *bb*, in the end views. The boiler is of the *wet-back* type, that is, the combustion chamber A, at the rear end of the furnaces is backed with a water space, B. The design also is that in which each furnace has its own combustion chamber, as indicated in the front view to the right and left. The water space surrounds each combustion chamber, and goes down underneath the furnaces. Manholes shown give access to the spaces below the furnaces, and there is a manhole at the top above the stays. The large end plate areas above the combustion chamber are tied together with sixteen bar stays *a*, all except the end ones being $2\frac{7}{8}$ in. in diameter, the end ones being $2\frac{1}{2}$ in. diameter. They are nutted inside and out. The upper stayed plates are thicker than the lower plates, which receive the numerous short stays and stay tubes. They are $1\frac{1}{16}$ in. thick, the latter being $\frac{13}{16}$ in. at back, and $\frac{3}{4}$ in. in front. Other bar stays connect the lower plates in the vicinity of the furnaces, seen in the view to the left.

The shapes of the combustion chambers can be gathered from a comparison of the longitudinal and end views. The middle one is nearly rectangular in outline, but the wing chambers have to follow on the outsides nearly the curve of the shell. The water space is greater above than below, as it also is at the back end, at B, to permit of the ready disengagement of the bubbles of steam. The correct fitting of these involves a neat bit of templeting and flanging. The tube plate and the back plate D are each made in a single steel plate, flanged inwards to receive the wrapper plate E, similarly to locomotive fire-boxes. The tube plate is $\frac{11}{16}$ in. thick, the back plate $\frac{9}{16}$ in. These plates are stayed so closely that all the stresses are borne by the stays. The suspension furnaces are flanged outwards at the back end, as shown at *c* and *d*, and riveted to the tube plates there. At the front end the front plate is flanged outwards at *e* to receive the parallel end of the furnaces.

The stays are vital parts of a boiler, and the parts which are the first to give trouble by leaking. When worked under unsuitable conditions of forced draught, the joints of the stay tubes in the tube plates are the locations of leaks. It is easy to see how vulnerable these may be when they occur in such large numbers. In each outer nest in this boiler there are 127 tubes, fitted at each end into back and front plates. In the middle nest there are 128 tubes. A large proportion of these are stay tubes, indicated by the thick circles in the end view to the left. All the tubes measure $2\frac{1}{2}$ in. in external diameter, and are of lap-welded wrought iron. The plain tubes are of 9 I.W.G., the stay tubes are $\frac{7}{16}$ in. thick. The plain tubes are fitted by expanding, the stay tubes are screwed. All are beaded over at the back tube plate.

The combustion chambers are stayed to the shell, and to each other, with numbers of solid screwed stays, seen in each view. Some are larger than others, the larger ones being $1\frac{7}{8}$ in. diameter. All others are $1\frac{5}{8}$ in. diameter. Each is screwed with eight threads per inch, and fitted with a nut at each end. They are made of Staffordshire cable iron.

The crowns of the combustion furnaces are stayed with bridge or girder stays F, secured with screws G. The girders are each built of two plates $\frac{5}{8}$ in. thick, riveted together with

ferrules to keep them apart. The bolts, $1\frac{5}{8}$ in. diameter, pass down between, and the nuts bear on washers which grip the edges of the girders.

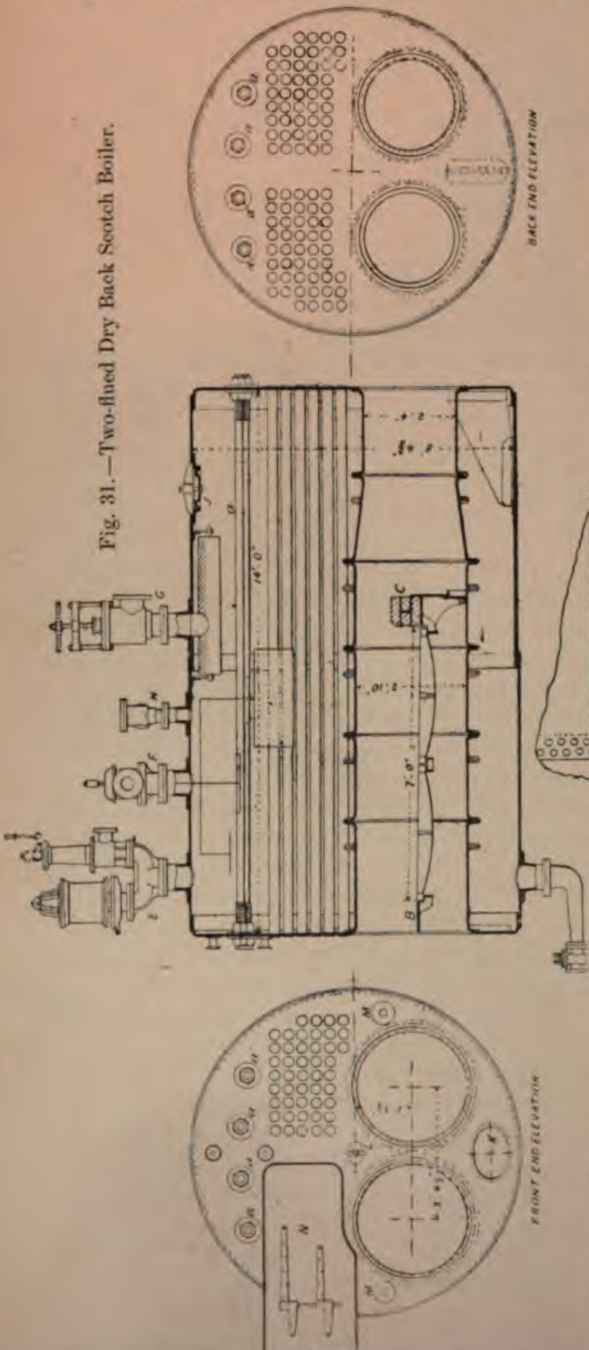


Fig. 31.—Two-flued Dry Back Scotch Boiler.

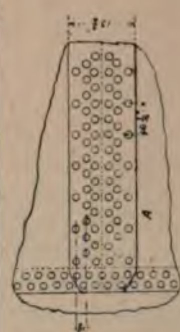


Fig. 31 illustrates a Scotch boiler by Tinkers, Ltd., measuring 8 ft. 6 in. diameter by 14 ft. long, for a working pressure of 140 lb., the test pressure being 240 lb. The furnaces are formed in plain rings united with Adamson flanged seams, and are reduced in diameter at the combustion chambers. Some leading dimensions are given. The rivets are $\frac{7}{8}$ in. diameter, and the holes are drilled to $\frac{15}{16}$ in. diameter. The detail at A shows the arrangements of rivets in the circular and longitudinal seams. The boiler ends are flanged to fit within the shell. The ends are tied together with four long stay bolts, *a*, $2\frac{1}{4}$ in. diameter, double nutted at each end, and by eighteen stay tubes. These, except that they are screwed at the ends (not indicated), do not differ from the other return tubes shown. There are 92 tubes, $3\frac{1}{4}$ in. diameter, lap-welded, and pitched at $4\frac{1}{4}$ in. centres. A gusset stay is used only at the rear end, below and between the furnace flues.

The various fittings and mountings are—the dead plate B and bridge C, with the fire-bars between; the blow-off bend and cock D, attached like all the other mountings to a stamped steel stool or seating; E is a duplex safety valve, one valve being of lock-up design; F is a safety valve by J. Hopkinson & Co., Ltd., which combines high steam pressure and low water alarm; G is a Hopkinson junction valve fitted with an expansion spindle to prevent risk of bending or breaking; H is an ordinary junction; J is the top manhole, of M'Neil's pressed steel design; K the bottom one, below the furnace, of the same type; L is a mud door; M M are the locations of the feed valves; N shows the position of one of the smoke box doors, the smoke box not being indicated.

Fig. 32 illustrates a four-flued, single-ended, wet-back boiler by Dunsmuir & Jackson, Ltd. It is 16 ft. 6 in. diameter, by 11 ft. 6 in. long. It is rated at 1,000 I.H.P. worked under natural draught, and working under Lloyd's survey at 170 lb. pressure. The following are the leading particulars of its construction, which will afford a good idea of the immense capacity

assive scantlings of a it-day marine boiler. otal weight of the boiler working is 77 tons 12 of which 26 tons 12 cwt. to the water, at the ng temperature. The heating surface is 2,660 e grate surface is $74\frac{1}{4}$; a ratio of—

$$\frac{\text{ating surface}}{\text{rate surface}} = 35{\cdot}8.$$

eating surface is divided —four furnaces 205 ft., ombustion chambers 390 d 280 tubes 2,065 ft. are 543 cub. ft. of space.

shell plates are two mber only, united with butt straps. The are $1\frac{7}{32}$ in. thick, the $1\frac{3}{16}$ in. diameter, in $1\frac{1}{4}$-oles. The strength of section is equal to 87·5 ent. of the solid plate, vet section 90 per cent. nner butt straps are $1\frac{1}{4}$ ick, the outer ones are n. thick. The end plates langed inwards within ell. The back end plate two portions, $1\frac{3}{32}$ in. above, and $\frac{27}{32}$ in. below, d with a $4\frac{1}{2}$-in. lap joint en in the view to the The front end plate med of three plates, lap d, the tube plate and joint being cut to fit the furnace mouths, as n in the view to the left. circular flanged seams each two rows of $1\frac{5}{16}$-in. , in $1\frac{3}{8}$-in. holes. The ntage of plate strength s 65 per cent., that of ivets is $52\frac{1}{2}$ per cent. oles are of course drilled ce.

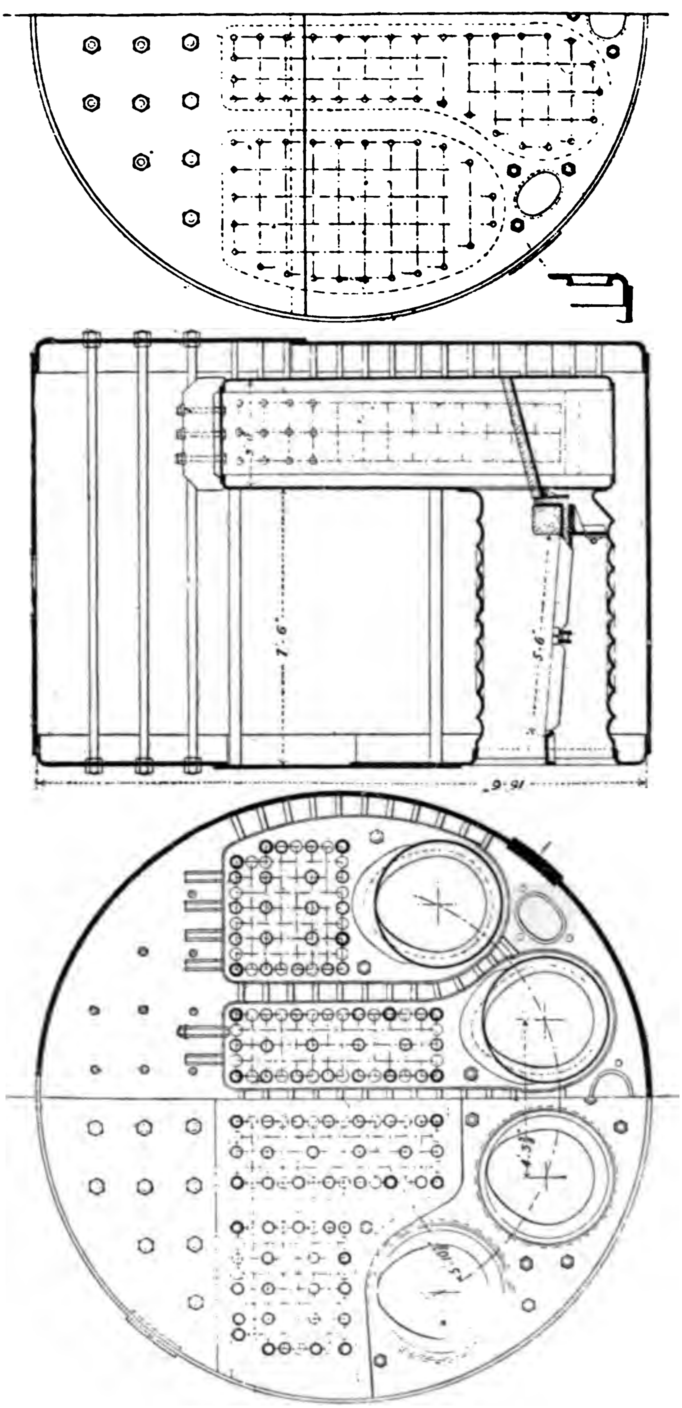


Fig. 32.—Four-flued Scotch Boiler.

The four furnaces are of Morison's suspension type, the steel being $\frac{1}{2}$ in. thick, and the internal diameter 3 ft. $4\frac{1}{2}$ in. Their method of attachment, and the grate fittings are clearly shown. The combustion chambers are of $\frac{5}{8}$-in. plate, facing the shell, stayed with $1\frac{5}{8}$-in. screwed steel stays; and $\frac{25}{32}$ in. thick for the tube plates. The roofs of the chambers are stayed with bridge stays of double iron plates, with bolts passing between.

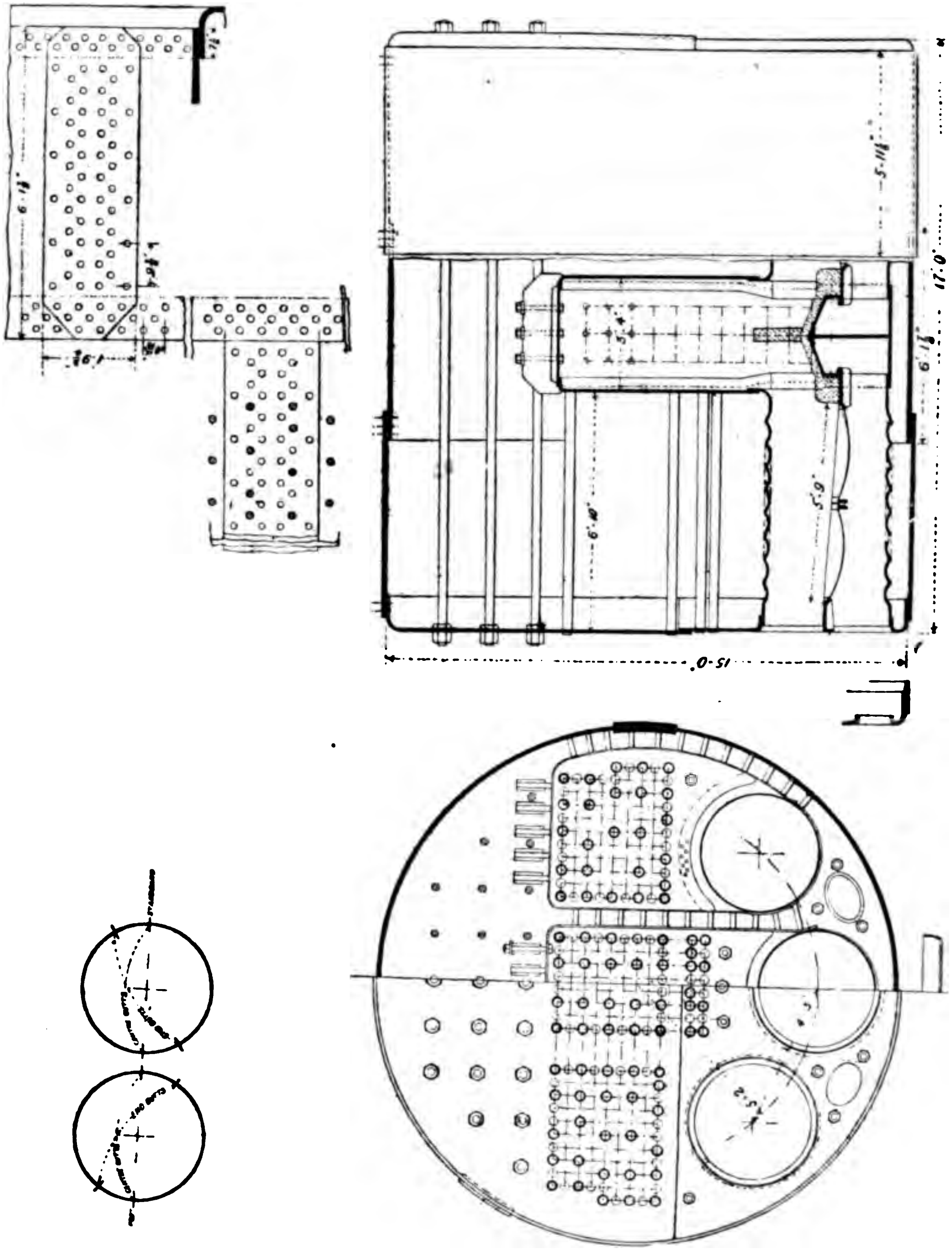


Fig. 33.—Double-ended Scotch Boiler.

There are 280 iron tubes in all, distributed among the four combustion chambers, and traversing a length of 7 ft. 6 in. between the tube plates. Of these, 192 are plain tubes, $3\frac{3}{4}$ in. external diameter, and No. 8 W.G.; 68 are stay tubes, shown in thick circles, $3\frac{3}{4}$ in. external diameter, by $\frac{5}{16}$ in. thick; and 20 stay tubes situated at the corners of the chambers are of the same diameter, but $\frac{3}{8}$ in. thick. There are a number of solid steel bar stays connecting the end plates, both in the steam and water space. The former, eighteen in number, are $2\frac{3}{4}$ in. diameter, screwed with eight threads per inch, and double nutted. Each stay has a net area of 5·268 sq. in. Those in the water space below the furnaces are $2\frac{1}{4}$ in. diameter, and the net area after screwing is 3·437 sq. in. There are four manholes, three at the back of the boiler below the furnaces, and one on top. Two of these boilers were made to the order of a Liverpool firm.

Fig. 33 shows a double-ended boiler by Messrs Dunsmuir & Jackson, Ltd. It is of that type in which a single combustion chamber is common to two furnaces at opposite ends. Some of the leading particulars are as follows:—

The working pressure is 190 lb. per sq. in. The total heating surface is 3,754 sq. ft., the six furnaces provide 276 ft., the three combustion chambers 250 ft., the tubes, 556 in number, 3,228 ft. The grate surface equals 115 ft. The ratio is: $\frac{\text{heating surface}}{\text{grate surface}} = 32{\cdot}6$. The steam space equals 666 cub. ft. The diameter is 15 ft., the length 17 ft. The shell is built up of six plates. Treble riveted lap joints form the inner circular seams, the longitudinal seams, double-butt strapped, have to break joint as indicated in the diagrams at the top left-hand corner. The shell plates are $1\frac{15}{32}$ in. thick, the rivets $1\frac{7}{16}$ in. diameter, the holes $1\frac{1}{2}$ in. The riveting is shown in detail at the top right-hand corner. The strength of the net plate section is 84·75 per cent., that of the rivet section 87·4 per cent., by the Board of Trade rule, or 90·5 per cent. by Lloyd's rule. The inner butt straps are $1\frac{11}{32}$ in. thick, the outer ones are $1\frac{1}{8}$ in. thick. The circular seams are double riveted to the end plates, treble riveted in the inner seams. There are slight differences in these, but the rivets are all $1\frac{1}{2}$ in. diameter, and the strength of the plate section is from about 63 to 68 per cent., and that of the rivets from about 50 to 65 per cent. All holes are drilled in place.

Of the tubes, 556 in number; 388 are plain, $3\frac{1}{4}$ in. external diameter, by 7 W.G.; 144 are stay tubes of the same diameter, and $\frac{3}{8}$ in. thick; and 24 fitting in the corners of the chambers are $\frac{7}{16}$ in. thick. The stay bolts which pass from end to end are $2\frac{7}{8}$ in. diameter above, and $2\frac{1}{4}$ in. below. The furnaces, bridge stays, and other details, are similar to those in the previous example.

Scotch Pig.—A grey open pig iron produced in the Clyde district of Scotland. It includes several brands.

Scotch Tuyere.—One in which the air passage is surrounded with, and kept cool by a coil of water pipes.

Scrap Iron.—This is a very important element in metal mixing for foundry work. Unless a firm is prepared to rely on pig of special grades to mix from, the use of scrap is essential and economical. It has the advantage of having been remelted once or more, and may often be purchased cheaply. There are also the wasters, the runners, and risers, and the broken and worn parts, and tools made for temporary service and discarded, which accumulate in all shops, and must be melted up. Scrap occurs in all grades from the poorest to the best, that from heavy machines ranking high in value. The quality of scrap is estimated by the aspect of its clean fractured surfaces, and an experienced furnaceman, or metal mixer, or foreman is able to judge with unerring accuracy of the value of scrap, and the most suitable proportions in which it may be mixed with certain brands of pig. If uniformity of quality is required to conform to specifications, or for similar work done day after day, then test bars are poured and tested. When time and space permit, it is well to make a rough separation of the scrap in a yard according to quality to lessen the work of subsequent sorting. Thus the light and heavy scrap will be separated, the grey from the mottled, and these from the white or the chilled irons, and from the inferior or burnt iron.

By light scrap is meant that which does not exceed 1 in. or $1\frac{1}{2}$ in. in thickness. It includes

the framings of old sewing machines, of stoves, water and gas pipes, and of small mechanisms and parts of mechanisms generally. It is soft and grey, the carbon being wholly graphitic. It melts harder, and so increases the strength of grey pig. One-third or one-fourth of such scrap may be added to the pig, its effect being to control or modify the quality of the latter. It yields comparatively little slag.

Heavy machinery scrap comprises large machine framings, gear wheels, beds and base plates, pumps and engine work, and that of kindred character. It is more or less mottled. The carbon is partly graphitic and partly combined, and there is less silicon present than in light scrap. It is suitable for heavy castings, and may be used almost entirely, or mixed with half its amount of pig.

There is a large quantity of burnt iron in some shops' scrap, as old annealing pots, furnace grates and bars, foundry stove plates, and other odds and ends which have been subject to the long continued action of heat. It yields an excessive amount of slag in melting, and is of little use excepting in small admixtures with metal for inferior castings, such as fire-bars. It melts white.

In a scrap heap there is generally a considerable proportion of foreign material. It comprises wrought iron and steel in the form of shafts, plate, bolts, rivets, and forgings, malleable cast-iron work, galvanised iron, &c. All these must be picked out and thrown aside.

Very heavy masses of scrap cannot be broken with the sledge hammer, like those of ordinary dimensions. For these, therefore, a ball of from ½ cwt. to 1 cwt. is employed, dropped from a crane by loosening a trigger. Sometimes holes are drilled and steel wedges inserted and driven in, so splitting up the mass. Or the large lumps are melted in the largest cupola, or on the hearth of a reverberatory furnace.

Scratch Brush.—The wire brush used by fettlers for brushing the sand off castings. Also a circular wire brush revolved at a high speed, and used in operations previous to polishing, plating, &c.

Screw.—The screw is one of the mechanical powers. Its relation to the inclined plane is seen by cutting out a piece of paper in the shape of a right-angled triangle, and winding this round a cylindrical rod. The hypotenuse then forms the spiral screw thread or helix, the slope of which is equal to the angle in the triangle opposite the perpendicular.

Considered as a machine, the screw works in a companion screw or nut, having a recess round it fitting the projecting thread of the screw. The nut or the screw may be free to move axially, but not to rotate, so that one or the other has a rotatory motion, but cannot move in the direction of its axis. Force is therefore never applied to a screw in the direction of its axis; it is made to revolve by applying a force at the end of a long arm projecting at right angles to the axis of the cylinder. As in the ordinary screw press, this arm generally projects in both directions, so that while one is pulled the other is pushed. Every time the arm makes a complete revolution the screw moves through a distance equal to the space between two consecutive threads, and in this way weights are lifted, as in the case of the screw jack, or resistance overcome, as in a press.

In considering the mechanical advantage of the screw, it is necessary, as in the case of the other mechanical powers, to suppose entire absence of friction—a fictitious condition. Let P represent the power (or the sum of the forces at the end of a lever); b, the length of the arm from the point at which power is applied to the axis of the screw; W, the resistance; and p, the pitch of the screw. In one revolution P acts through a distance equal to the circumference of a circle whose radius is b, that is, $2\pi b$, and the work done by the power in one revolution is $P \times 2\pi b$. In the same time the screw has moved a distance equal to the pitch p, and has, therefore, done work equal to $W \times p$. By the principle of work, $Wp = P \times 2\pi b$, and the mechanical advantage is thus $\frac{W}{P} = \frac{2\pi b}{p}$. To work at a mechanical advantage $\frac{W}{P}$ must be greater than unity, and therefore the less the pitch of the screw and the greater the radius of the arm or lever, the more advantageous is the screw. Under heavy loads the friction is very considerable.

Fly Press, Jack, Piles, Screw ng, &c.

gination of Screws.—All screws which are to-day are copies of pre-existing ones. The engineers were compelled to originate their screws before they could begin to take . There were two methods of doing this—gineers' method, as used by Maudslay and others, and that of the astronomical ment makers, as employed by Ramsden. is no similarity between the two, unless it t the inclined plane formed the basis of but the methods of its application bore no blance to each other.

methods employed by engineers were upon the fact that an inclined plane l around a cylinder develops a screw. It eresting to know that this method of ating was described by Pappus, a Greek matician of the fourth century. It was use of by Antony Robinson late in the teenth century at the Soho Works, Birmam, and by this means he cut a tripleled screw 6 in. diameter and 7 ft. long, of section. Paper was cut to encircle the . Upon it a number of parallel oblique were marked representing the inclination screw threads corresponding with their This being cemented round, a number centre punch marks were popped round lines. The paper was then removed and ps connected with a fine line made with a The thread spaces were then cut with a and file as accurately as practicable. Then was cast around the screw, retained withcast-iron box, the box being fixed. To ox, cutters were attached, and these were o correct and finish the thread, the screw traversed through the nut, and past the s by hand. At Soho Foundry, Birmingthere were recently square-threaded screws, threads to the inch, 10 or 12 ft. long, had been cut with hammer and chisel.

viously such a method is incapable of prog even an approximately true screw, and the screws of our modern lathes would appear t by comparison therewith. And as the refined methods of the astronomical instrumakers have not been applied to the eers' screws, it is evident that the modern screws have been derived from such rude originals. This applies not only to long screws, but to short taps and to dies and internal threads of nuts. Little conception can be formed by us of the time and tedious labours spent by the early mechanicians on the corrections of original screws. As a perfect screw, using the term in its workshop sense, could not be originated, and as a perfect screw was essential to the production of all other screws, including taps, and dies, an infinite amount of labour was for many years devoted to this task. The correctional methods varied, but they consisted mainly in producing dies upon original screws and using them to cut new screws, by which the errors present in the first would be partly reduced.

Ramsden's method of cutting an original screw was by means of a screw and tangent wheel, which moved the cutter along synchronously with the revolution of the screw blank. But this was only suitable for short screws. Another method of originating short screws only, was by means of an inclined plane, the tool slide being pulled over against the inclined plane while the latter was drawn along in a direction transversely to the tool slide. Another still in use is by means of a chasing tool, the edge of which is serrated to a counterpart of the screw threads, the tool cutting correctly by virtue of the angle of rake, or lead given to the serrations. Short screws, both external and internal, are commonly *struck*, and cut by means of these tools, and screws already cut by other means, are eased, or smoothed and polished by the same tools. These are not suitable for originating screws of over 2 in. or 3 in. in length. Holzapffel states that Maudslay employed a cutter fixed in a block to slide along a triangular-bar lathe which, from the description, would seem to have been a chaser having a single cutting edge only. It was hollowed to fit the cylinder, and fixed at the required angle in the block, and it is stated that some hundreds of screws were thus made, and their agreement with one another was in many instances quite remarkable. On the whole he gave the preference to this method of originating screws. To Maudslay, even more, perhaps, than to Sir Joseph Whit-

worth, we are indebted for our modern screw threads.

In the production of a master screw almost infinite pains have been taken to effect minute corrections during the period of cutting the screws, or in the cutting of successive screws, each one more accurate than its predecessor. Such methods are, of course, quite inadmissible in engineers' work, yet they have afforded lessons by which engineers have benefited, and the accurate and rapid screw production of to-day is a heritage from the labours of many skilful mechanicians in the past.

Screw Area.—*See* **Screw Propeller.**

Screw Barrel.—*See* **Crane Drums.**

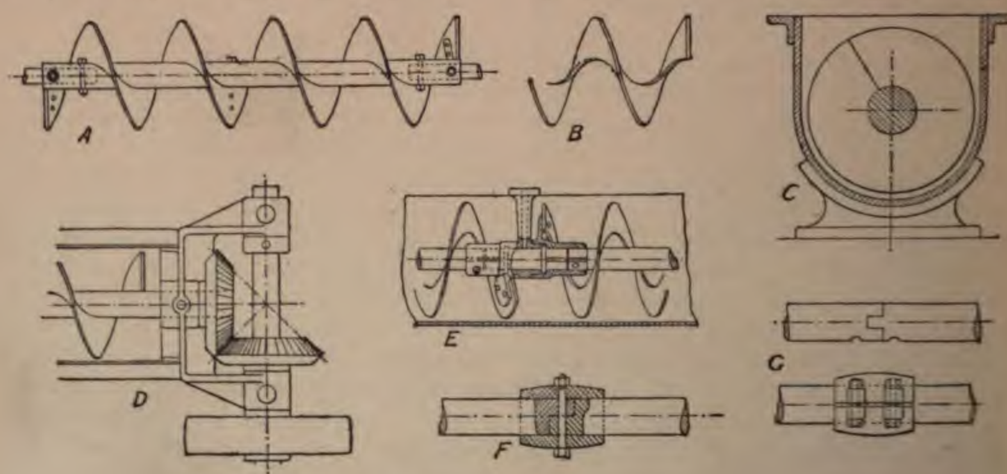


Fig. 34.—Screw Conveyors.

Screw Bolt.—*See* **Bolt.**

Screw Conveyors, or **Spiral Conveyors.**—The employment of a screw or spiral to propel materials along within a tube or trough is very common, where such materials as ashes, small coal, earth, flour, phosphates, sand, and anything sufficiently small have to be transported. The screw carries the stuff along in a continuous manner, to be dropped at the end of the trough, or at intermediate spouts or gates. The troughs are of wood, lined with sheet steel, or of cast iron, or entirely of steel. The spirals or flights are secured to solid or hollow shafts by plates or brackets, Fig. 34, A. The flights, being of thin steel plate, B, offer little resistance to driving, and propel the material with a minimum of friction. C shows a section through a trough and its stand, while D illustrates the ordinary method of driving the shaft by mitre gears and belt pulley. An intermediate bearing to support the shaft is shown at E. It is dust-proof, to prevent damage from the material being conveyed. Shafts are united in various ways with couplings, two of which are illustrated at F, and G. The first is a half lap, the second a tenoned joint.

Screw Cutting.—The formation of screw threads by a purely cutting action, as distinguished from their production by simple pressure, as in **Thread Rolling.**

The methods of screw cutting include that done in the common screw-cutting lathe, which is the subject of the present article. Also by means of chasers in die heads, as in **Screwing Machines.** By **Dies,** and **Taps** operated by hand, or in **Automatic Screw Machines,** by chasers held in the hand, or operated in the **Chasing Lathe,** or by methods of origination.

As a screw is essentially an inclined plane wound round a cylinder, two movements are necessary for producing it in a lathe—the rotation of the cylinder, and the traverse of the cutting tool. These two movements must have precise relations for any one screw, but they vary with all variations in the screws cut. The period of rotation of the lathe spindle must coincide exactly with the traverse of the tool, which corresponds with the pitch of the screw

cut. This is effected for hundreds of le variations in pitch either by retarding, elerating the rotation of the guide screw, feeds the tool longitudinally in its rest. : pitch of the guide screw is unalterable, riations are produced through the medium change wheels, for a description of which

1ange Gears.

re is no mystery about the arrangement se gears, though the number of rules given es confusing. The basic facts to be tted to memory are those of *ratios*. The nental rule which covers all cases is—*The of the guide screw is to that of the screw to , as the number of teeth on the mandrel is to that of the number of teeth on the screw wheel.*

.s, say the lead screw has two threads per ind a screw of six threads to the inch has cut, then $\frac{6}{2} = 3$, and 3 must be the ratio en the wheels. Say a 20-toothed wheel the mandrel, then $20 \times 3 = 60$, the wheel ed on the lead screw. Suppose that the to be cut is of 1 in. pitch, then the ratio 2, and with, say, a 40-toothed wheel on andrel, one of 20 teeth only would go on ad screw. In the first case, the rate of on of the screw to be cut is *accelerated* y three times faster than that of the lead and the thread is *finer*. In the second he rate of rotation of the screw to be cut *rded* to half the rate of that of the lead and the thread is *coarser*. Therefore it s, if in doubt where to place the larger maller wheels, that when the thread to is of *finer* pitch than that of the lead the *smaller* change wheel must go on the *rel*, and the *larger* on the *guide screw*. hen the thread to be cut is of *coarser* pitch hat of the lead screw, the *larger* change must go on the *mandrel*, and the *smaller* : *lead screw*. These are the rules which be committed to memory. All others have with alternative methods, and with the que of the various conditions which arise, ave to be dealt with in screw cutting.

ple, and Compound Trains.—The differ- etween simple and compound trains arises. irst are suitable for threads as fine as about twelve to the inch. But for finer threads, and also for very coarse threads, two wheels are not sufficient to give the ratio required, the extremes in a set being only 20 and 120, or 6 to 1. The centres of mandrel and lead screw being fixed do not permit the inclusion of very large wheels, even with the accommodation afforded by the swing plate. The compound train, which may include two, four, six, or more pairs of gears, solves the difficulty.

In the compound train the calculation is similar, with the difference that instead of taking single wheels, the *products* of all the drivers, and the products of all the driven are taken, and then treated just as though they were single wheels. Thus, if the drivers were 60 and 80, and the driven 30 and 20, the ratio would be $\frac{60 \times 80}{30 \times 20} = \frac{4800}{600} = 8$, giving the relation 8 between the guide screw and the screw to be cut.

To obtain the numbers of teeth in the change wheels from the ratio, fix on one wheel arbitrarily, and divide it by the ratio to obtain the other. Thus in the ratio $\frac{6}{2} = 3$, the following would be correct: $\frac{60 \text{ teeth}}{3} = 20$ teeth, $\frac{90}{3} = 30$ teeth, $\frac{120}{3} = 40$. Or, conversely, multiply $20 \times 3 = 60$, $30 \times 3 = 90$, $40 \times 3 = 120$.

Or a Rule of Three sum can be made. Say a 20-toothed wheel is selected for the spindle, and the other wheel is wanted to cut a thread of eight to the inch, with a guide screw of 2 pitch. Then $2 : 8 :: 20 : 80$, showing that an 80-toothed wheel is required on the guide screw.

It is usual to obtain the wheels for changes by a process of adding ciphers to the numbers which represent the pitches of the lead screw and screw to be cut, following the custom of denoting a pitch by the number of threads per inch, as two threads = 2 pitch, four threads = 4 pitch, and so on. So that, taking a lead screw of two threads per inch, and a screw to be cut of eight threads per inch, the fraction $\frac{2}{8}$ becomes $\frac{20}{80}$ for the wheels, a device which can be evidently made to effect many changes, all having the same ratio, and which, away from the simpler pitches, becomes very useful in the

simplification of calculating change gears. For instance, the following have the same ratio as $\frac{20}{80}$, and they utilise the change wheels in a set, $\frac{20}{80}, \frac{25}{100}, \frac{30}{120}$; and if the ratio were less, a larger number could be selected. It is especially useful in compound gears where two or more sets of wheels admit of variation individually, so long as the ratio is maintained.

A compound train is conveniently broken up as follows:—

Having a ratio, say, $\frac{\text{24 threads per inch to be cut}}{\text{2 pitch of guide screw}}$.

The sequence may be taken thus—

$$\frac{24}{2} \times \frac{6 \times 4}{2 \times 1} = \frac{60 \times 40}{20 \times 10}.$$

But a 10-toothed wheel is not in a set, so—

$$\frac{\overset{120}{\cancel{60}} \times 40}{20 \times \underset{20}{\cancel{10}}}, \text{ or } \frac{60 \times \overset{80}{\cancel{40}}}{20 \times \underset{20}{\cancel{10}}}, \text{ or } \frac{60 \times \overset{120}{\cancel{40}}}{20 \times \underset{30}{\cancel{10}}}.$$

The ratio 12 being retained in all.

Pitches involving fractions must be reduced to whole numbers by multiplying by the denominator of the fraction. Or the number can be treated decimally. For instance, a pitch of $6\frac{1}{2}$ threads per inch can be set down as 13, or as 6·5; one of $6\frac{1}{4}$ threads as 25, or 6·25, and the equations carried out to maintain the proper ratio. Thus, to cut $6\frac{1}{2}$ threads per inch, with a lead screw of 2 to the inch, the equation would stand $\frac{6\frac{1}{2}}{2} \times 2 = \frac{13}{4}$, a ratio of 13 to 4. Wheels may be deduced thus: $\frac{13}{4} = \frac{130}{40} = \frac{65}{20}$, which wheels 65 and 20 will cut the thread. Or taking $6\frac{1}{4} = \frac{6\cdot25}{2} \times 4 = \frac{25\cdot00}{8}$, giving a ratio of 25 to 8—

$$\frac{25}{8} = \frac{5 \times 5}{2 \times 4} = \frac{50 \times \overset{100}{\cancel{50}}}{20 \times \underset{80}{\cancel{40}}} \text{ wheels required.}$$

To test wheels, reverse the operation of calculating them by ratio. Thus for a simple train, divide the number of teeth in the driven wheel by the number of teeth in the driver, and multiply the result by the number of threads per inch in the lead screw. Thus, to cut six threads per inch with a lead screw of 2 pitch, using 20 and 60 wheels, $\frac{60}{20} = 3 \times 2 = 6$. For a compound train, divide the *product* of the driven by the *product* of the drivers, and multiply the result by the number of threads per inch in the guide screw. Thus, to cut twenty-four threads per inch with a 2 pitch guide screw, using wheels, say—

$$\frac{60 \times 120}{20 \times 30} = \frac{7200}{600} = 12 \times 2 = 24.$$

To cut prime numbers, fractions have to be dealt with, because primes are not divisible by the two, or four threads of standard lead screws, without leaving a remainder. 3, 5, 7, 11, 13, 17, 19, &c., cannot be divided by 4, or 2, as 4, 6, 8, 10, 12, &c., can. Hence it becomes necessary to look up compound trains. Thus, to cut seventeen threads per inch with a lead screw of two threads per inch, $\frac{2}{17} = \frac{20}{170}$ would not do, because a 170 wheel is not in a set, therefore say—

$$\frac{2}{17} = \frac{2 \times 1}{17 \times 1} = \frac{20 \times \overset{50}{\cancel{\overset{100}{\cancel{10}}}}}{\underset{85}{\cancel{170}} \times \underset{100}{\cancel{10}}}, \text{ wheels required.}$$

Some lathes have lead screws of three threads per inch, and as 3 is a prime, such lathes give more trouble in calculation than those with two and four threads per inch do.

Sometimes the problem is put in a way that does not take account directly of the number of threads per inch to be cut. So many threads are wanted in a certain length. Then the question is reducible to one of ratio. Say sixteen threads have to be cut in a length of 20 inches, with a lead screw of two threads per inch. Then in a length of 20 inches of the lead screw there are forty threads, giving a ratio of $\frac{40}{16}$. Then, say, $\frac{40}{16} = \frac{10 \times 4}{2 \times 8} = \frac{\overset{50}{\cancel{100}} \times 40}{\underset{60}{20} \times \underset{40}{\cancel{80}}}$, requiring two 40 wheels. Or, say, $\frac{50 \times \cancel{40} \text{ drivers}}{\underset{30}{\cancel{20}} \times 40 \text{ driven}}$.

Metric pitches are cut on lathes having metric lead screws, but they can be cut with sufficient accuracy with the English lead screws by including a wheel of 63 teeth, which leaves an error of $\frac{1}{240}$ in. on the length of the metre; or one of 127 teeth, which reduces the error to $\frac{1}{1000}$ in. It is again a question of ratio. The length of the metre is 39·37079 in., and this contains 1000 millimetre threads. In an English lead screw with two threads per inch there will be in the metre length 39·37079 ×

·74158 threads. The ratio between the therefore—

$$\frac{78 \cdot 74158 \text{ threads of } \tfrac{1}{8} \text{ in. pitch}}{1000 \text{ threads of 1 mm. pitch}}.$$

t a closer approximation to an equal r for the English thread, reduce each y $\frac{1}{5}$, which will give $\frac{62 \cdot 99727}{800}$, or practically r the ratio. To obtain change wheels ed, the lead screw figure will remain con- while the millimetre unit 63 will be lied by the number of millimetres in the to be cut. Thus, for a pitch of 12 mm. uation will stand—

$$\frac{\times 12}{0} = \frac{756}{800} = \frac{\overset{120}{63 \times 12}}{\underset{100}{10 \times 80}},$$ the wheels required.

ching Threads.—Except in unusual cases, ere a fine thread can be cut at one tra- of the tool, it is necessary to bring the ck several times to cut gradually deeper the thread is finished. The clasp nut has released, the carriage racked back, and the ut in for the succeeding traverse. Some have backing belts which reverse at a speed, and then it is not necessary to out the clasp nut; but this is unusual. lathes are fitted with a screw catching suitably indexed, but these are not ous. In the great majority of instances, ore, the turner has to catch threads with- y aids.

cutting threads which are of the same as the lead screw, or which are multiples, quot parts of the same, the clasp nut can opped in anywhere. and the tool will the thread right. Thus, with a lead screw threads per inch, threads can be cut of 8, 12 to the inch. The test is to divide umber of threads to be cut by the pitch lead screw, as $\frac{12}{2} = 6$. When there is no nder, the clasp nut will engage anywhere. usual to run the carriage back a little r than the spot where the actual screw ences, say about an inch from the end, to he tool a start.

en division cannot be done without leaving ainder, then the point to work out is to ascertain the number of threads which will be even with those in the leading screw, without leaving a remainder. If the lead screw has two threads per inch, then the fractional or odd thread to be cut must be brought into an even number, until a ratio is obtained at which multiples of two threads will coincide exactly with multiples of the pitch to be cut. Five threads per inch would be even in a length of 2, 4, 6, or 8 in., but not in a length of 1, 3, 7, or 9 in. $2\frac{1}{2}$ or $3\frac{1}{2}$ threads per inch will come even numbers at 4 or 8, or 12 in. $2\frac{1}{4}$ or $3\frac{1}{2}$ threads will be even numbers at 8 or 16 in.

It must be remembered that bringing the numbers even may not coincide with the length of screw to be cut. For instance, instead of 8 in. in the last paragraph, the length wanted may be 12 in. Then the carriage would have to be brought back 16 in., or 4 in. away from the starting point of the screw. Or in ordinary cases where a screw starts from the end of a piece, the distance to which the carriage will be brought back must be included in the ratio of even numbers. In these jobs the carriage can be set by a mark on the bed, or against a block inserted between the foot of the poppet and the carriage, or against the poppet directly.

Multiple Screws.—These are cut by setting the tool as many separate times as there are threads to the screw, the difficulty being to set the tool equidistantly. A common method is to select a mandrel wheel that will divide equally to suit the screw, twice for a two-threaded, three times for a three-threaded screw. The first change wheel which gears with it has one tooth marked with chalk, and the tooth space with which it engages in the mandrel wheel is also marked. This corresponds with the position for cutting one thread. To cut the next, lower the swing plate, and turn the mandrel round until the next space, the half, or third, as the case may be, is brought into engagement with the marked tooth on the first change wheel, which is the position that corresponds with the cutting of the next thread.

The Tool Gauge.—The shape of the tool is tested by a screw thread gauge, having recesses of 55° or 60° or other angles to suit different threads. The tool is set in the rest by the gauge, either for internal or external work.

The faces or edges of the tool are ground away to give sufficient clearance to leave the cutting edges free without interference from the edges of the thread. As the angle of a thread varies with diameter, and is greater on a small than on a large diameter, this has to be borne in mind when grinding tools. No trouble due to this arises in the vee threads. But in square threads and worm threads, interference occurs unless the tool is ground by a properly developed drawing. This will be found noticed under **Square Threads**.

Threads of Steep Pitch.—In cutting these the difficulty is that large compound trains have to be fitted to obtain the rapid traverse, and the strain is so great that the belt slips, or the teeth of the gears become stripped off. Hence the practice has long been to reverse the method of driving, by putting a pulley on the end of the leading screw, and belting it from the line or countershaft. The belt is removed from the cone pulley in the headstock, its mandrel being driven from the lead screw through the change gears, or opposite to the usual direction. The speed is slow, but the wheels are safe.

A few lathes embody arrangements designed to avoid this makeshift device. Provision is made for driving through the back gears instead of from the spindle, so that power is gained, and excessively large gearing-up of change wheels is avoided. But the work of this kind is being removed from the common lathes, being done better by a milling operation as described under **Screw Thread Milling**.

Screw-Cutting Lathe.—This term is applied only to those lathes in which a lead or guide screw and change wheels are employed, and the cutting done with a single-edge tool. Machines in which screws are cut by other agencies are specially designated and described as automatics, chasing, screwing, screw lathes or machines, being more or less designed for repetitive work. The great value of the screw-cutting lathe is that it is suitable for cutting screws of any sizes, pitches, and lengths, within the capacity of the lathe, following on turning or boring, without removal of the work. It is therefore indispensable in the turnery, but when repetitive work is being done, the other machines are employed more economically.

The ordinary lathe of this type is described as *self-acting sliding, surfacing,* and *screw cutting*. These movements include, besides the lead screw and change wheels, the back shaft or feed rod of the ordinary turning lathe, and usually a distinct set of gears, or a belt for operating the latter. Around these elements many variations are found.

The older English practice, still retained in many cases, is to locate the lead screw in front of the bed, and the back shaft behind it, driving the first through the change gears, the second through a belt or gears. The movements of the slide rest are derived from the screw through a clasp nut; and from the back shaft through a worm splined to the shaft, driving a worm wheel having its spindle bearings in the carriage, and whence the longitudinal traversing, and cross surfacing movements of the slides are derived, through friction cones operating the motions, the longitudinal by a rack and pinion at the front, the cross traverse or surfacing by a screw.

In the American design the back shaft is transferred to the front just below the lead screw, and is termed the *feed rod*, and this arrangement has been gradually embodied in many English and Continental lathes. It possesses several advantages over the older form by reason of its snug character, in consequence of which the gearing up, and driving, and feeds are simplified. It permits the same set of gears to be used for screw-cutting and feeding. The conical feed discs are also much larger, being enclosed in the apron instead of being on spindles in the carriage. The same reverse can be used for the screw and feed rod. In many modern lathes it is not necessary to go to the rear of the headstock to reverse, but this operation may be performed at the front of the headstock, or at the slide rest.

An up-to-date screw-cutting lathe is a very different machine from those of a few years since. In many recent lathes the screw or feed shaft can be started and stopped while the lathe is running, yet it is impossible to have both running at the same time. Four screws of different pitches can be cut without stopping the lathe. Lead screws are better protected than formerly with long guards. Nuts are

onger. Often a table of change gears saves he turner the trouble of calculation.

For details of the screw-cutting lathe, *see* **Change Gears, Clasp Nut, Lead Screw, Slide Rest,** &c.

The ordinary engineers' self-acting sliding, urfacing, and screw-cutting lathe still retains nany of the essentials of its original, most comlete development, those, namely, of a machine or sliding, surfacing, screw-cutting, boring, aper turning, and wheel and other turning of arge diameter. So that in a limited degree t is almost a universal tool, universal still in sense which cannot be claimed by any other nachine tool. But because of its comprehensive haracter it suffers from practical drawbacks. t is not economical or desirable to use the ame lathe in succession for cutting long, and hort screws, for turning shafts, and short tuds and pins, for turning flywheels, boring ear wheels, turning pulleys, &c., in the gap. his necessitates frequent changes in rigs-up, n methods of chucking, in gears, in tools, roducing unequal wear of slides, and so costs noney. Moreover a good mechanic is required o operate one of these lathes efficiently, wheres if the work is subdivided among special nachines, men earning two-thirds the wages— n some cases boys at one-fourth the wage—can ttend to them. Generally, too, the work will e done more efficiently when put on special nachines. The foregoing remarks emphasise he fact that the tendency in machine tools ow, as in many other matters, is towards pecialisation or differentiation. Universal nachines are not in request. Hence the lathe, he prince of engineers' machines, is not used o the extent it was formerly for boring, milling, screw-cutting, or grinding. The boring nachines take all heavy boring, much of which vas formerly rigged up on the lathe saddle, he milling machines perform practically all nilling that is now done, screw-cutting of a epetitive character on pieces of moderate length, s nearly always done now in screwing machines, nd in lathes with hollow mandrels; and grinding, the very suggestion of which causes a hudder in the mind of the lathe man, is relegated to the grindery. Even the turning of small tuds and pins required in quantity is not done in the common lathe, but in a special stud, or capstan lathe. So that the functions of the common

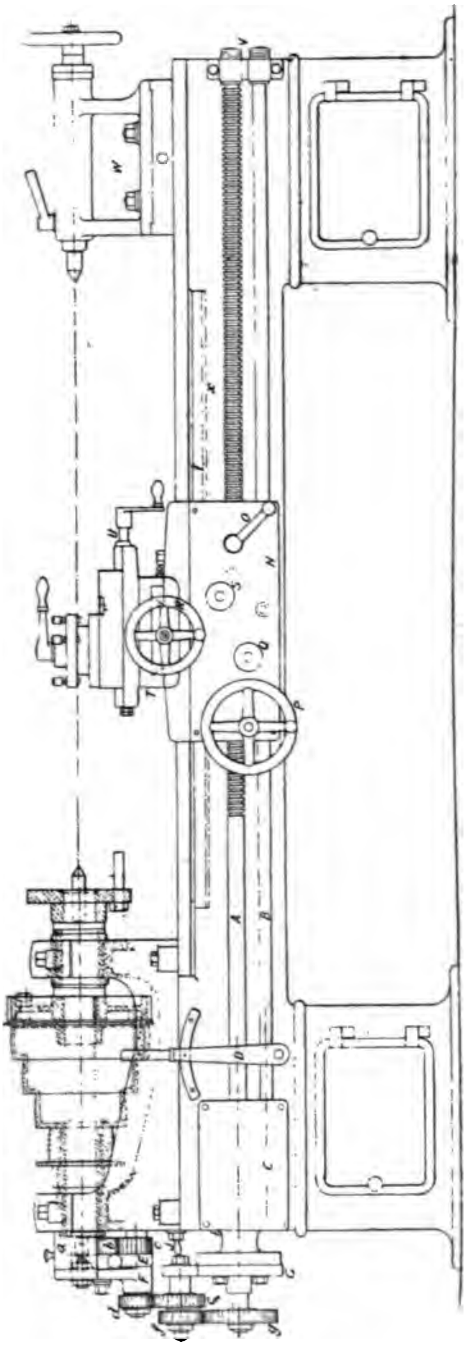


Fig. 35.—Screw-Cutting Lathe. (Front Elevation.)

lathe are nearly restricted to turning, surfacing, light boring, and the cutting of long screws.

An example of a 10-in. screw-cutting lathe of modern design with the feed rod in front is shown in Figs. 35 to 39, made by Cunliffe & Croom, Ltd.

In the general views, Figs. 35 and 36, A is the lead screw, and B the feed rod. The latter is operated from one set of gears enclosed in the box C, by means of the lever D. This is a far more convenient arrangement than the older one with a back shaft fitted. We will commence our observations at the headstock end, and trace the motions to the slide rest. Compare Figs. 35 and 36 with enlarged details given in subsequent drawings.

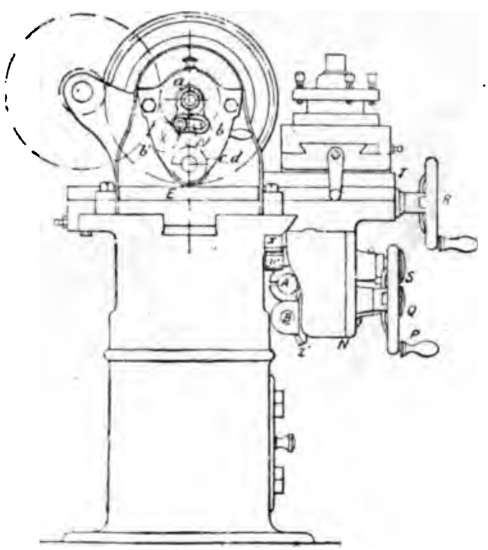


Fig. 36.—Screw-Cutting Lathe. (End Elevation.)

At the rear end of the headstock spindle, the first pinion, *a*, in the train is fast. It drives the pinion *c* through either of two pinions, *b*, or *b′*. These are fitted to give rotation in two directions from the spindle, which is done by carrying the spindles of *b* and *b′* on a reversing plate E, moving within the fixed plate F, which is bolted to the end of the headstock. A pinion, *d*, on the same spindle as *c* drives gears *e*, *f*, and *g*. *g* is the last or driven gear on the end of the lead screw A, on which also the quadrant plate G swings (see Figs. 35 and 37), and carries the movable stud H, used when setting up trains of change wheels.

The pinion *c* is on a spindle which passes through to the interior of the headstock, Fig. 37, and carries there a pinion *h*. *h* engages with a wheel, *j*, the spindle of which is carried on a swinging plate, H, moved by a handle, J, and locked by a nut. This is for throwing the wheel *j* into or out of engagement with the wheel *k* below, which puts the feed shaft B into or out of action. The feed shaft is thus driven from another short shaft, K, on which the wheel *k* is keyed, Fig. 37, and this carries three wheels, *l*, *m*, *n*, of different sizes, engaging with three wheels, *o*, *p*, *q*, on the lead screw (compare with the plan view in Fig. 37). The wheel *r* on the feed shaft is driven by the wheel *q* on the left-hand end of the lead screw, so that the two drives are connected, the feed rod through the lead screw. Yet neither can be in at the same time because the wheel *n* which connects to *r* runs loosely on its shaft K. The various gears are put into engagement by the movement of the lever D at the front of the lathe, whence a shaft goes into the bed, and throws over the forked lever L, and actuates the plunger M within the shaft K. The shaft K is slotted through a certain length, shown in the views, in which a key, *s*, slides, and is engaged with key grooves in the wheels *l*, *m*, *n*, according to the three positions of the lever D, and giving roughing, medium, and fine feeds to the shaft B. The cuts are 8, 16, and 32 per inch respectively, obtained by the lever without stopping the lathe.

Going to the slide rest, Fig. 38, we see at once how the fittings are simplified by comparison with those of lathes in which a back shaft is fitted. The whole of the mechanism is concentrated at the front, and nearly all concealed by the apron N. The various handles, &c., operated in front are as follows:—

The lever O throws the clasp nut *t* into and out of contact with the lead screw, shown separately in the detail, Fig. 38. P is the handwheel by which the racking traverse is actuated through gears *u*, *v*, *w*, the latter engaging with the rack *x*. The same sliding motion is put in by power by means of the knob Q through the friction *y* thus:—A pinion, *z*, splined to the feed rod B, seen in Fig. 38, engages with a wheel, *z′*. As *z* is splined to the feed rod, it must turn with it and turn *z′*. On the same

spindle as z' a pinion, *aa*, is keyed, and this engages with a wheel, *bb*, which is therefore always running when the feed rod is running. When the friction cone *y* is pulled into this wheel, it turns the pinion *cc*, which engages with the wheel *v*, on the same shaft as the rack pinion *w*.

The transverse movement of the rest is effected

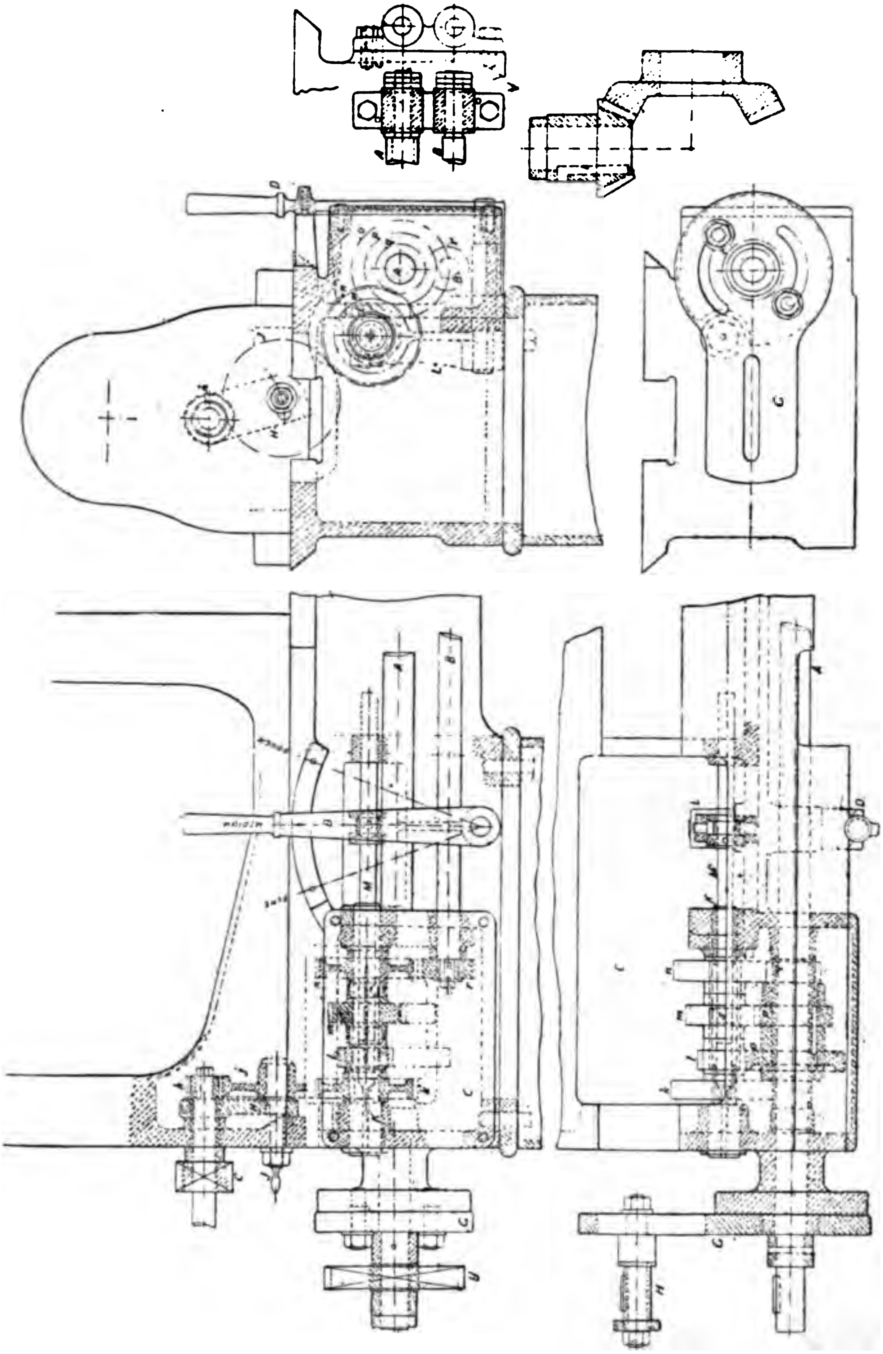


Fig. 37.—Screw-Cutting Lathe. (Change-speed Gears, &c.)

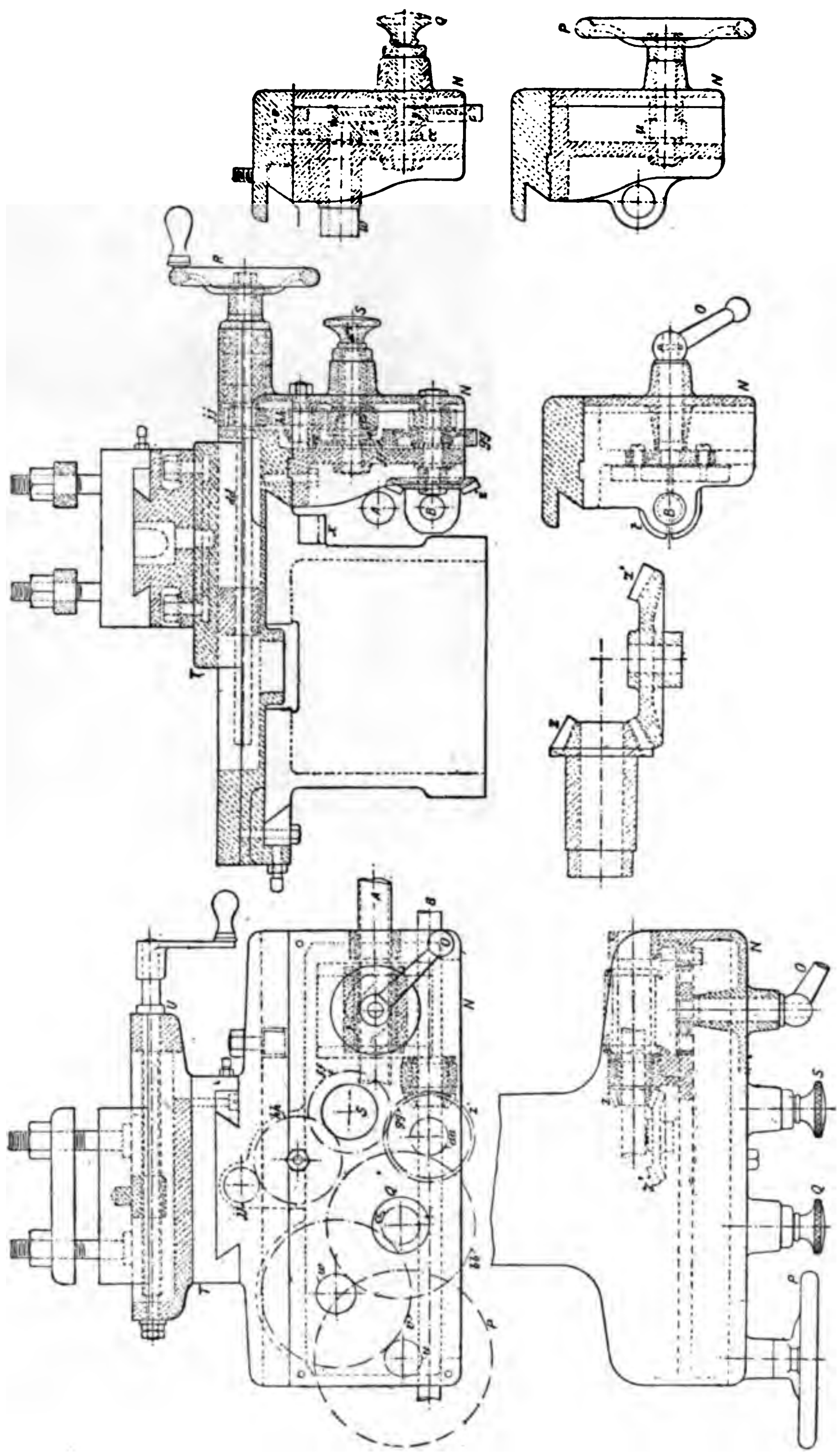


Fig. 38.—Screw-Cutting Lathe. (Slide Rest, and Gears.)

by the hand-wheel R which turns the screw *dd* in its nut. The power movement is produced by turning the knob S, which pulls in the friction cone *ee*. Then the wheel *ff* on this cone is driven from the wheel *gg* keyed on the same spindle as the bevel wheel *z'*. *ff* then drives gears *gg* and *hh* to *jj* on the end of the cross traverse screw *dd*.

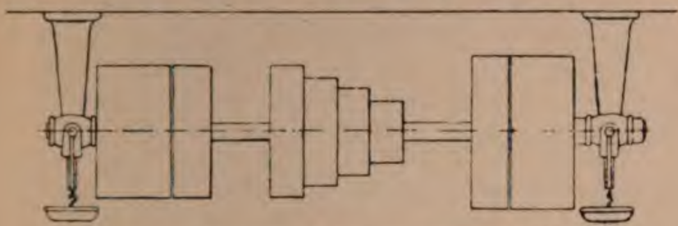


Fig. 39.—Countershaft for Screw-Cutting Lathe.

The remaining features of the lathe may be disposed of briefly. The upper portion of the slide rest is of the usual design, with full swivel of the tool holder by the tee-head bolts on the base T. Hand feed of the tool holder is by the screw and handle U. V, Fig. 37, shows the fitting of the lead screw, and feed rods, with their screwed washers. The poppet W, Fig. 35, has cross traverse for taper turning. The headstock is back geared, with a ratio of 8·82 to 1. The countershaft, Fig. 39, is of two-speed type, the pulley diameters being respectively 16 in. and 14 in. It makes 150 and 250 revolutions per minute. The bed is 12 ft. long. The swing over the carriage is 15 in. The lathe weighs 48 cwt.

Screw Gears.—These assume three forms—the worm, the spiral, and the helical. The differences between these may be variously defined. A *worm* is either a single, or multiple complete threaded screw. A *spiral gear* is a slice cut out of a multiple-threaded screw at right angles with its axis. A worm has a short pitch or *lead*. A spiral gear, if completed, would have threads of greatly extended pitch or lead. A worm must engage with a wheel having a considerable number of teeth, seldom less than a dozen, and generally twenty and upwards. A spiral gear can engage with a fellow having an equal, or a lesser, or greater number of teeth. Usually worms and wheels have their axes at right angles; it is exceptional to set them at other angles. But screw gears are equally adaptable for working at any angle.

When the axes of a pair of screw wheels are set in the same plane instead of at right angles, they are termed single helical wheels, or *helical wheels* simply. An important result is, that instead of the severe sliding friction of the screw threads, the rolling contact of the helical teeth is substituted. And when the helical wheels are duplicated, back to back, with teeth at opposite angles, the *double* helical wheel is produced, in which the diagonal thrust of each series of teeth is neutralised. We have therefore the fact that these types of gears, though usually considered apart, are closely related, and can be therefore better understood when studied in common.

The three figures represent diagrammatically three types of screw gears, Fig. 40 being a screw or angle wheel, Fig. 41 a worm and worm wheel, and Fig. 42 a helical or double helical wheel. Say, there are 12 teeth in Fig. 40, 24 teeth in Fig. 41, and 26 teeth in Fig. 42, that would simply mean that in those cases the teeth are sections of many-threaded screws whose helices number respectively 12, 24, and 26, the axes of the cylinders of these screws corresponding with the lines A-A in each case. Hence there are certain relations common to all, however much those relations may differ in proportions, and the gears in function.

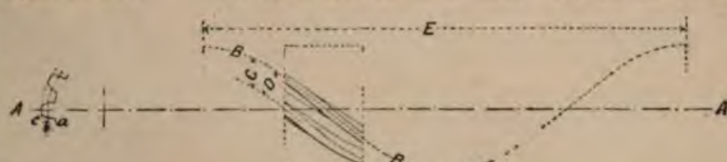


Fig. 40.—Screw Gear.

The helices can be continued in each case to right and left, as shown by the dotted lines B-B, until they have made one complete revolution of their respective cylinders, and then the length measured on the axial line A-A would be equivalent to their pitch, regarded as screw

threads, and termed the *total axial pitch* or *lead*. This total distance is divisible into as many parts as there are screw threads, and each such distance would be the *divided* axial pitch. The latter pitch may, however, be dismissed as being of little or no practical value in gear construction, but the total axial pitch is required when cutting spiral gears on a machine. The distance C in the figures, measured around the circumference of the plane cutting the axis transversely, taken from centre to centre of teeth, is the *circumferential*, or *circular* pitch, and this, if multiplied by the number of screw threads, will give the total circumference of the wheel. This, and the *normal* pitch D in the figures are the pitches which are most used in practice. D is constant for any wheels which gear together, this is imperative, but C will vary according to the angles at which the wheel axes are placed. But C always retains a fixed relation to D, and either can always be readily calculated from the other, and the angles of the axes.

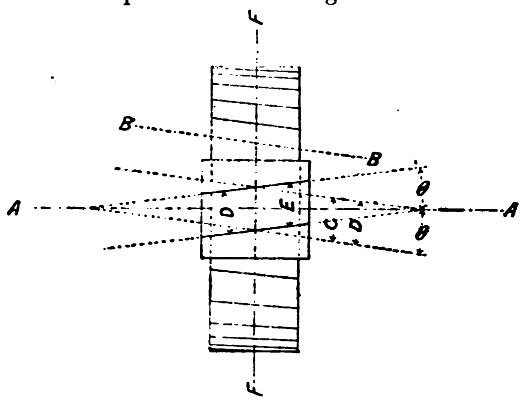


Fig. 41.—Worm Gears.

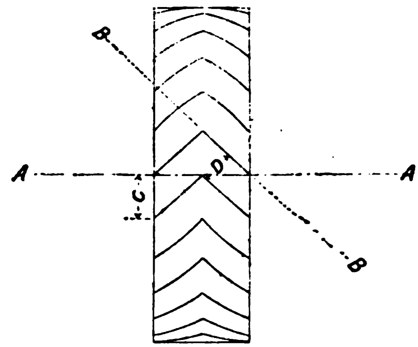


Fig. 42.—Double Helical Gear.

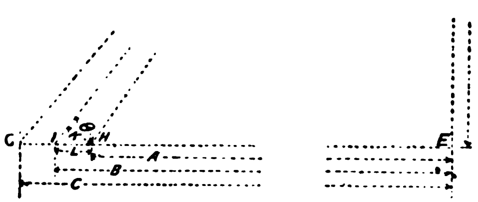


Fig. 43.—Diagram of Tooth Angles in Spiral Gear.

In wheels of the type of Figs. 40 and 42 there is a considerable difference in the dimensions of C and D, but in wheels like Fig. 41 there is not much difference. Again in wheels like Figs. 40 and 41 the action is that of sliding only; in Fig. 42 it is rolling pure and simple. In each case also the velocity ratios may be equal or unequal. In Fig. 40 they will be equal when there is the same number of teeth, *i.e.*, screw thread sections in each, and set at the same angle, unequal when the threads or the angles, or when both vary.

Screw wheels, Fig. 40, may work into spur wheels or into racks, and *vice versa*, and the normal pitches alone need be equal, the others may vary. In Fig. 41 the velocity ratios are commonly very unequal, the worm seldom containing more than two, or three threads, oftener one only, to several in the wheel. In any case, the circumferential pitch C of the wheel must equal the pitch E of the worm, the pitch E being the distance from centre to centre of contiguous threads, and equal to the total axial pitch in a single-threaded worm, and to the divided axial pitch in a double or treble-threaded worm. Fig. 42 may be made of any sizes, and are the helical wheels first suggested by the stepped gear of Dr Hooke.

Having now established the relations between these, we will take each form in detail and work out the relative proportions, and note the merits or otherwise of each.

In Fig. 40 two teeth are shown of a spiral gear with the point, pitch, and root lines, *c*, *b*, *a*, drawn, and the continuation of the pitch line to the completion of an entire revolution of the screw thread B, giving the total axial pitch E. The sum total of the pitches C gives a definite

dimension—the pitch circumference of the wheel, which is represented by B in Fig. 43, and the corresponding diameter by C in Fig. 44. But, as the circumferences are different at tooth root, and point from that of the pitch circumference, the effect is to give a very marked twist, or difference of angle at those points, just as in any screw blade, corresponding with *a*, *b*, *c*, Fig. 40. In Fig. 44 the relations shown are those on the pitch plane, and F is the breadth of the wheel. Hence, if we lay down triangles in Fig. 43, where B = the total circumferential pitch, or sum of C in Fig. 40, × the number of teeth, and make the angle θ represent the angle which the pitch

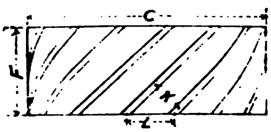


Fig. 44.—Screw Wheel.

surface of the screw thread makes with the perpendicular to the axis, Fig. 43, we have on the completion of the triangle, D = the total axial pitch or lead, = E in Fig. 40. Then setting off the distances A and C equal to the circumferences *a* and *c* respectively in Fig. 40, the lines FH and FG represent the angles which the spiral tooth centres make on these planes.

From the same diagram the relations between the normal and circumferential pitches can be determined graphically. Since the normal pitch is perpendicular to the pitch axis of the screw thread, set that down in the diagram, Fig. 43, as at K, and then L will represent the circumferential pitch. Conversely the latter being laid down, the former can be measured. To determine the relations trigonometrically (compare with Fig. 44):—

$$L = \frac{K}{\sin \theta}.$$

$$K = L \times \sin \theta.$$

Having two wheels of the same diameter and angle of teeth, the normal and circumferential pitches will be alike in each. But with any alteration in angle the latter will alter, becoming increased or diminished, with increase and diminution of angle respectively. The latter, therefore, govern the diameters of spiral wheels, not the normal pitches. Two wheels thus gearing together with axes at right or any other angles will, if their teeth differ in angle, have circumferences not proportionate to their velocity ratios. The extreme case is when one of the gears is a spur tooth rack, or wheel, and the other a screw rack, or wheel, since in the spur teeth the normal and circumferential pitches coincide.

When two screw wheels gear together, the angle which their axes make with each other differs according to the *handing* of the threads. With gears whose threads are of the same hand, whether right or left, the angle of the axes will equal the *sum* of the angles of the threads, so that $45° + 45° = 90°$ angle of axes. But when the threads are of opposite hands, the angle of axes is equal to their *difference*, as $45° - 45° = 0$, and the axes are parallel. Then at once we have helical wheels, with the very important result that the sliding of teeth due to the crossing of their axes is absent, pure rolling contact taking its place. *See* **Helical Gears, Spiral Gears, Worm Gears**.

Screwing Dies.—*See* **Dies**.

Screwing Flange.—A flange which is used for wrought-iron and other pipe, being threaded on the interior, instead of being brazed.

Screwing Machines.—The function of these is to produce screw threads upon tubes and plain bars, either black, or bright, without doing any turning, or other operations, which are properly the work of the screw machines, and the lathes. Dies or chasers are used, fitted in a fixed or a revolving head, so that they are capable of small adjustments for diameter, and of a rapid opening movement to clear the work after screwing. The type of machine described under **Bolt Screwing Machine** is typical of most. The chief variations are noticeable in the methods of driving, and the size of the heads. Hand-driven machines are useful for situations where power cannot be applied; the hand shaft is geared up with two or three gears to the revolving spindle, to give sufficient power, at a suitably slow rate. A handle is sometimes placed on the second spur gear shaft, for getting quicker speeds, on light work. Pipe screwing machines require large spindles, to allow the pipes

to pass through. Pipes up to 13 in. diameter can be dealt with on the largest machines, the threads being cut at one going over. A cutting-off attachment is employed in connection with most pipe machines; it is fastened to the front face of the die head, and carries a transverse cutting-off blade, held in a slide, which is fed inwards as the attachment revolves, by a screw and star wheel, in a similar manner to the facing arms fitted to boring bars. A vee steady opposite the cutting-off tool bears on the pipe and prevents it from springing away from the tool.

Some examples of screwing machines by Charles Winn & Co. are shown in Figs. 45 to 48, Plate III. Fig. 45 is a hand-driven machine, having a pair of spur gears connected up to a bevel gear drive on the spindle; two purchases may be obtained, by placing the crank handle either on the first pinion boss, or upon the spur wheel boss, so regulating the speed and power according to the work being done. Bolts up to $1\frac{1}{2}$ in. diameter, and 2 in. tubes can be screwed. The carriage is racked along the bed, and its vice has duplex jaws, to give a firm hold. The back pair of jaws can be taken off when it is desired to screw close up to the heads of bolts, or to hold bends. The die head carries four chasers, which may be adjusted radially to cut various diameters, and may also be thrown back instantaneously to release work after it has been screwed, by moving the bow lever handle.

Fig. 46, Plate III., is a machine for tube screwing only, with a capacity up to 8 in. The saddle has a duplex grip vice, and in order to obtain sufficient power, the tightening handle is geared with spur pinions up to the operating screw. The die head has five chasers, which are adjusted to diameter by a cam ring. The driving takes place through a stepped cone (not visible) at the front through double purchase spur gears to the bevel wheel on the spindle.

Another function is included in the tube screwing machine, Fig. 47, Plate III., that of nipple making. The die head in this case is held on the sliding carriage, and the tubes are gripped in the chuck of the revolving spindle. There is a small slide behind the die head, having front and back tools for cutting-off tubes. This slide is free to move along on vee ways, so that when a tube is screwing its way through the dies, the end of the tube coming into contact with a disc-faced stop on the slide pushes the latter backwards; at the same time the operator turns a handle feeding in the parting-off tools, until the tube is severed, leaving a nipple. The rest of the tube is still being screwed, so that the operations go on without intermission. It will be evident that such cutting-off could not be accomplished unless the slide carrying the tools was carried along at the same rate that the tube moves. The grips in the headstock chuck are adjusted within a certain range of diameters, and the gripping and release are effected by turning the large star handle, which operates a gear segment, moving the bow lever.

Another tube screwing, cutting-off, and nipple making machine is illustrated in Fig. 48, Plate III. The general construction resembles that of Fig. 47, but the head is double geared, having a four-stepped belt cone at the back, acting through two sets of spur gear. The tube is supported in the back end of the spindle by four steady jaws, adjustable for diameter. The die head and carriage resemble those in Fig. 47, but an addition is made in the shape of a pair of steel vee steadies, which steady the tube while it is being cut off.

Screw Jack.—*See* **Jack.**

Screw Key.—A **Spanner.**

Screw Pile.—*See* **Piles.**

Screw Plate.—A small steel plate, with one or two handles for turning it by, and furnished with several holes for cutting screw threads. It is only used for diameters not exceeding $\frac{1}{4}$ in., the friction being too great for larger work. The cutting edges are formed by holes or slots adjacent to the threaded holes.

Screw Press.—*See* **Fly Press.**

Screw Propeller.—The germ of the screw as a means of propulsion may be traced to the "spiral oar" which was suggested by James Watt. Many years elapsed before it assumed practicable forms, but it has wholly displaced paddles for ocean service. The efficiency of paddles lessens with lightening of the load, due to the consumption of coal on a long voyage, while that of the propeller is unaffected. Moreover the paddle boxes offer much resistance to winds and seas.

Fig. 45.—Hand Screwing Machine.

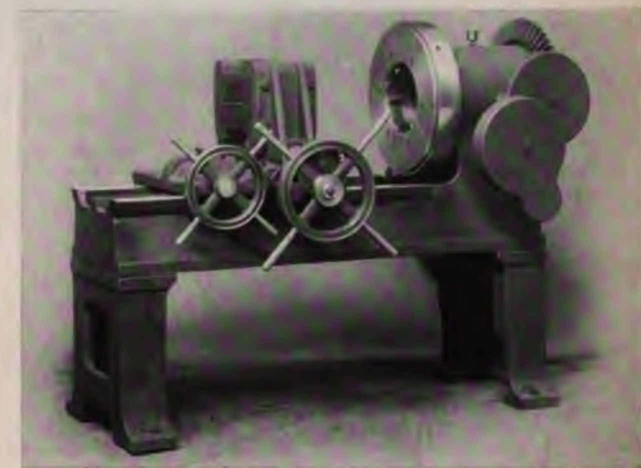


Fig. 46.—Pipe Screwing Machine.

Fig. 47.—Pipe Screwing Machine.

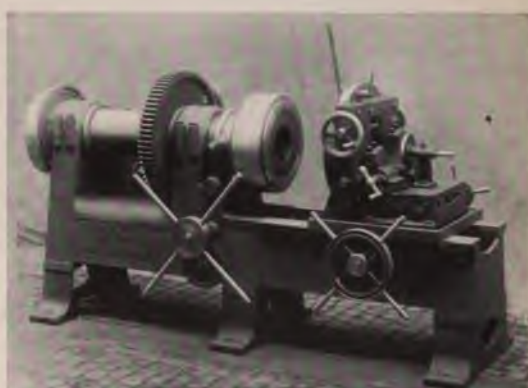


Fig. 48.—Large Pipe Screwing Machine.

(Charles Winn & Co.)

The Forms of Propellers.—Essentially these comprise segmental blades which are portions of multiple-threaded screws, two, three, or four in number. The screws are of very coarse pitch, of large diameter, encircling a small cylinder or body, being therefore nearly "all blade." The following are the terms used in connection with screw propellers.

The *pitch* is the distance measured from face to face, or centre to centre of a thread, when it has made one revolution round its body. It is the *axial* pitch of the screw. A *true screw* is the common screw, in which the pitch is regular, and which has therefore the same angle throughout. A screw with *increasing* pitch has variable angles. The increase may be *radial*, in which case the pitch of the blade is finer next the boss than at the tip, the *tip* denoting the periphery of the blade. A decrease of pitch of from 10 to 15 per cent. is usually given. The effect is, that the churning action of the blade next the boss is lessened, and the hold of the blade on the boss is increased. A pitch may vary *longitudinally*. Pitches are also varied in both directions in the same blade. In fact there are several modifications involving variations of pitch in screw propellers.

The *area* of a blade is that of the surface of the blade. The *disc area* is that of the circle described by the tips of the blades. The apparent *slip* of a propeller is the difference between the actual advance of the vessel, and that which should be due to the speed of the propeller, supposing it worked in an unyielding substance. It varies from about 10 to 25 per cent. It is the difference which should be run as given by the engines, and the actual distance run by the vessel. *Negative* slip is of the opposite character. It occurs when a stream of water is thrown outwards and backwards by the propeller, the space of which is partly filled by a following stream which produces additional thrust on the propeller. It is an evil to be avoided, showing that the screw is not working at its best efficiency. The *driving surface* is the flat, or after face of the blade. The *leading edge* is that which enters the water first, the other is the *following* edge.

The screw propeller owes nothing to pure theory. Numerous papers have been written on the subject, bristling with formulæ. Yet, to-day, often when the best possible results are desired, propellers of different pitches and designs have to be tested on new vessels, unless experience of precisely similar vessels is available. Simple though the propeller appears there is nevertheless much obscurity regarding its very elements. Erroneous ideas were long held respecting friction, slip, and the action of the water, matters which are not fully understood even now. Mr Froude's experimental investigations have done much to clear up disputed matters, especially in regard to the friction of propeller blades, and the resistance of the edges. So important are these that attempts have been, and are made to lessen friction by such devices as filing and polishing the blade surfaces, by encasing them in sheet metal, and by covering up the bolt heads with metal, or cement, when blades are bolted to their bosses. The action of the displaced water on the propeller blades is a difficult subject, as is also the percentage of slip which yields the most economical results. At one time it was held, adhering to the analogy of a screw passing through an unyielding substance, that all slip was necessarily wasteful, and many attempts were made to reduce this or to get rid of it altogether. It is now known that a screw working with little slip is wasteful of power, and that a very considerable amount of slip is an essential to economy.

The practical result is that every different type of vessel must have its own different type of propeller; whether liner, battleship, torpedo boat, merchant vessel, and whether large or small, and dependent, too, on engine power and on speed sought. Hence the almost infinite variations in form. A propeller which gives good results on one ship, working under one set of conditions, will not be successful in another vessel under different conditions.

The three photographs, Figs. 49 to 51, Plate IV., illustrate examples of propellers made by Messrs John I. Thornycroft & Co., Ltd. In these types, the feature is that each blade is curved in the direction of its length in such a way, that, assuming the blade to be cut in a plane passing through the axis of the propeller, and through the centre of the blade in a direction parallel

to the said axis, the section of the blade is convex on its driving face, and this curvature is such that throughout its length it acts as directly as possible upon the stream of water passing through the propeller. In the direction of the diameter of the screw, the pitch of the blades is increased from the boss towards the centres of the blades at or about which the pitch is greatest, and thence it gradually decreases towards the outer extremities of the blades, and the pitch of the blades is increased in the direction of the screw's axis towards the rearward end of the screw.

Too much importance has been attached to the forms of patented screws. Often the screw itself is not at fault when it does not give results so good as another, but it is not so suitable for the vessel, and the engines. Hence trials are made with new vessels of different screws, and with variable pitches until the best are found. In any screw, essentials are, to design the blades so that each will take its fair share of the work, and to have them smooth to lessen friction.

Mr Maginnis once summed up the ideas of experts regarding the blades of screw propellers thus:—"The blades of the propeller have been made of almost every possible shape, form, material, number, and pitch—one proposing that they should be bent forward, another that they should be bent backward, another that the point of the blade should be in advance of the root, another that the root should be in advance; another that the blade should be straight; another that the horizontal sections of the blade should be concave; another that they should be convex; another that they should be the shape formed by an actual screw thread; another that they should have a large diameter; another that they should have a small diameter, and so on, until the owner or engineer of a steamship knows not which to act upon, or what to do; and the strangest thing of all is that they are supported by tabulated statements and records showing the superior advantages of the so-called improvements."

The first screws comprised a single blade forming a portion of a true screw. Afterwards a double helix was used, forming portions of two true screws. It was found gradually that improved results were secured by reducing the areas of the blades, the vibration being lessened thereby, and so gradually the present relatively small blades were developed. In still water the two-bladed propeller answers very well, but not in rough seas, where three, or four blades are used. The three-bladed propeller is more suitable, but the risk of the fracture and loss of a blade entails more serious consequences in regard to the ill-balancing than it does in a four-bladed propeller. Hence the latter is generally preferred.

Materials.—Propellers are made of cast iron, steel, gun-metal, phosphor bronze, manganese bronze, delta metal, aluminium bronze. The objection to cast iron is its weight, and liability to fracture, but it is used largely in the mercantile marine, being so much cheaper than the copper alloys. The weight of the latter can be reduced, but not in the proportion corresponding with equal strength. Cast iron when used must be of a tough mottled mixture.

The objection to propellers of cast iron besides that of excessive weight, and liability to fracture is the severe corrosion which goes on, and especially on the back of the blades. Mr Maginnis thought that this is due to the formation of some chemical, by the mixing of the atmosphere and salt water, which attacks the iron. The water having been partly displaced by the descending blades, a partial vacuum is formed at the back of the blades, which draws in water highly charged with air, which will be carried down into the water by the blades. Steel is stronger than cast iron, but more costly, though less so than gun-metal and the more expensive copper alloys which are ten or twelve times more costly than cast iron. The objection to steel is its liability to rapid corrosion, which is more rapid than that which goes on in cast iron. Hence various proposals have been made for coating blades of iron and steel with paints, and with sheathings of metal.

An interesting example of what ill-usage manganese bronze will endure is seen in Fig. 52, Plate IV. This shows a blade taken from the wreck of the *s.s. Yeoman* of the Harrison line, wrecked off the Portuguese coast; it will be observed that the blade is bent nearly double,

Fig. 49.—THORNYCROFT PROPELLERS.

Fig. 50.—THORNYCROFT PROPELLER.

Fig. 51.—THORNYCROFT PROPELLER.

Fig. 52.—MANGANESE-BRONZE PROPELLER FROM A WRECK.
(Billington & Newton, Ltd.)

To face page 60.

without fracture. Messrs Billington & Newton, Ltd., were the manufacturers.

Blades of manganese bronze do not fracture, but only bend with a blow. They have about double the strength of those of gun-metal. Experiments have proved that the difference in the first cost of propellers of manganese bronze and those of steel or iron is recouped by the saving in coal and speed. Thus, a vessel, the *Ballarat*, on a voyage to Australia and back gave the following record. The diameter, pitch, and surface of the propellers were alike :—

Material.	Speed.	Coal per Day.	Indicated HorsePower.	Slip of Screw.
	Knots.	Tons.		Per Cent.
Steel blades	12·11	63·8	2,828	13·1
Bronze ,,	12·35	55·0	2,577	9·7

These figures give the mean for the entire voyages. They show an increase of ·24 knot per hour, and a saving of 8·8 tons of coal per day by the use of the manganese bronze propeller, or a saving of 715 tons on the voyage, equal to about half the first cost of the bronze blades. Propeller blades of bronze alloys do not corrode as do those of iron and steel. Therefore they have not to be made heavier than necessary in order to allow for reduction of weight by corrosion. Moreover being scarcely liable to fracture they are made lighter than those of iron and steel, so lessening the strain on the stern frame of the vessel.

Manganese bronze propellers are poured at the tips of the blades, and the scum runs and rises into a head over the boss. Single blades are cast vertically with the tips lowermost. The metal is led in at the bottom and rises to the boss. The moulds are blackened with kaolin instead of charcoal.

Built-up Propellers.—The earlier propellers like many made now were cast with the blades solid with the boss. But experiences of delays due to broken blades has led to the general abandonment of this practice in favour of casting the blades separately, and bolting them to the boss. The flanges and bolts are frequently cemented over, or covered with sheet metal to form a smooth outline. This is from two to three times more expensive in first cost, but the fracture of a blade of a solid propeller will cost much more in the delay occasioned. If a second propeller is not carried as spare, several weeks will elapse before a new one can be made and fitted, and the vessel may have to be dry docked. If a single blade is broken off a built-up propeller, dry docking is not necessary, a lightening of the ship aft being sufficient. Moreover an entire spare propeller is a bulky article to carry, and awkward to attach, while a single blade occupies less space and is easily fitted.

Fastenings.—The fastening of a propeller on its boss is effected by a nut and keys. The nut must be threaded in the opposite hand to the rotation of the propeller to avoid risk of its working loose. The keys must be fitted well, or they will work loose, or become sheared off, which has often happened. The fit of the shaft in the bore must also be perfect. The weight of a propeller is so great, and the stresses to which it is subjected in rough seas so severe, that bad workmanship is soon evident. The bosses are bored with a taper of from 1 in 12, to 1 in 18—the first for large, the second for propellers of ordinary sizes.

Developments.—The angle of the tip of the blade is obtained readily by the following method. Set off the centre line or axis of the screw as a horizontal. On it erect a perpendicular, of length equal to the radius of the screw. From this line set off a horizontal distance on the centre line equal in length to the pitch, divided by 2π. Thus, horizontal length $= \frac{\text{pitch}}{6{\cdot}28}$. The hypotenuse connecting the horizontal and vertical gives the angle at the tip. For angles at other locations, divide the vertical into equal distances and draw lines thence to the end of the horizontal.

The method of setting out the sections of a screw propeller will vary according as the pitch is that of a true screw, or of one with increasing pitch, and whether it is right, or left handed. In a right-hand propeller the upper blade turns from left to right when looked at from the rudder end of the vessel. Fig. 53 shows the development for a right-handed screw of true pitch drawn for five sections. The radial section is drawn first

to give the blade thickness. Then a horizontal line, a-b, is drawn through the axis and extended sufficiently far to allow of setting off a proportion of the pitch. As the radius of the blade is taken, the circumference will be 2π. Therefore the pitch divided by 2π will give the proportional length c of the pitch. Or if the pitch is multiplied by the reciprocal of 2π, the result will be the same. In a pitch of say 12 ft., or 144 in., the length c would equal:—

$$\frac{144}{6 \cdot 28318} = 22 \cdot 89 \text{ in.};$$

$$\text{or, } 144 \times 0 \cdot 159 = 22 \cdot 89 \text{ in.}$$

Then set off the points of equal division on the blade, and draw lines through these, d, e, f, g, h, drawn through a point, d, on the blade, to b and b', and the angles which these lines make with the axis give the angles for leading and after edges respectively. e, e represents the width of the blade.

Development of Sections.—To mark out these, proceed as follows:—The section through the middle of the web of the blade and the boss is drawn, Fig. 57. An approximate rule for thickness at the root a is $\frac{1}{2}$ in., if in cast iron, for every foot in diameter of the propeller; $\frac{3}{8}$ in. in steel, and $\frac{7}{16}$ in. in gun-metal. Thence the thickness tapers down to the tip, where it is as thin as is consistent with safety, or from $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. The boss may be solid,

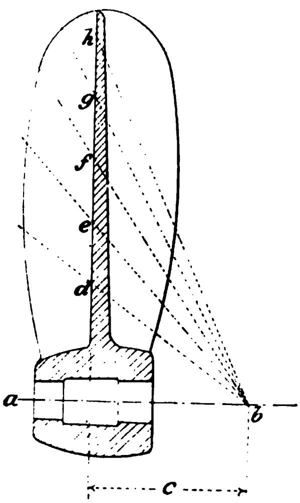


Fig. 53.—A True Screw.

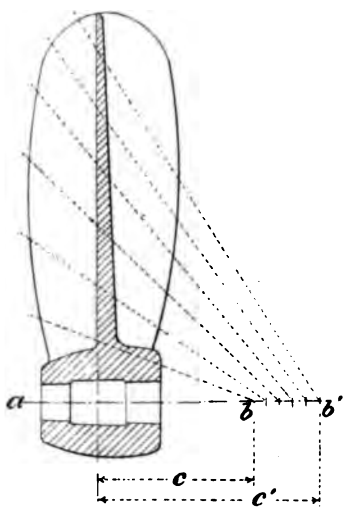


Fig. 54.—Screw with Pitch Increasing from Root to Tip.

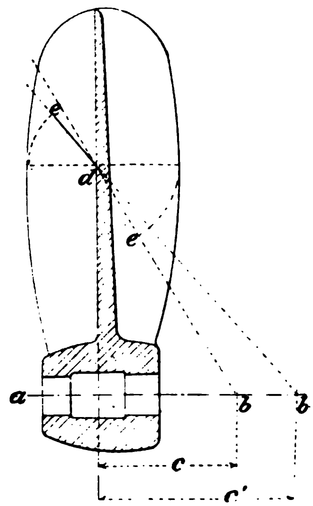


Fig. 55.—Screw with Pitch Increasing Longitudinally.

from the extremity of the line c, which will give the angles required.

In the case of a pitch increasing from root to tip, set off the least and greatest pitches, Fig. 54, at c and c' respectively, obtained as just stated. Divide both the blade and the distance between b and b' into the same number of equal parts, and draw lines as shown connecting these points, so giving the various angles to the blade sections.

For a propeller having a pitch increasing longitudinally, the pitch of the leading edge and that of the after edge is divided by 2π, and set off at c and c', Fig. 55. Lines are

or hollow. The development of the blade is obtained at various sections, usually varying from four to six. The circumference is developed to a definite scale, and the angles obtained therefrom. Divide the blade length from the tip to near the boss equally as 1, 2, 3, 4, 5, 6, and draw lines thence to meet the point b on the axis, Fig. 56, obtained as stated in connection with Fig. 53. These lines will give the angles of the blade faces at those sections. The widths of the sections correspond with the developed blade widths at those locations, that is, measured on the true width of the blade face, Fig. 57, 1′, 2′, 3′, 4′, 5′, 6′, and

are marked with radii from the blade centres as shown, Fig. 56. The width of the blade in the plane of the axis, Fig. 57, is obtained from the edges of the section in Fig. 56, measuring

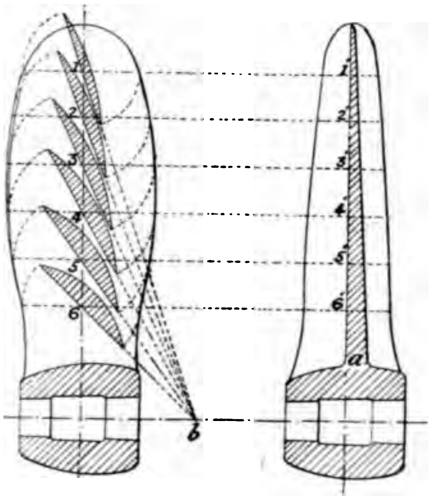


Fig. 56. Fig. 57.
Development of Blades.

horizontally from the centre line and setting off from the face of the blade in Fig. 56 as a centre line. The thicknesses correspond with the sections of the blade in Fig. 56. Having the widths and thicknesses, radii are adapted to each section, giving the shapes as indicated in Fig. 56.

Measuring Pitch.—The pitch of an existing screw may be obtained by means of a templet termed a pitchometer. It comprises two strips or arms adjustable for angle. The two may be retained after setting by screwing a strip across the free ends, or a permanent quadrant piece may be fitted to clamp the arms when set, as in Fig. 58. As the angle of a blade varies with every difference in radius, the instrument takes an angle which is correct only for the position in which it is set, the radius of which must be measured at the time. It is set by sighting one arm A parallel with a straightedge, B, laid across the propeller boss, and when this is parallel, and the other arm C is in contact with the face of the blade, the arms are clamped by the quadrant nut.

The radius R at which the instrument has been set is measured, and the circumference deduced therefrom. If the circumference is laid down as a base line, and the angle as the hypotenuse, and the perpendicular measured, the latter will be the pitch of the screw. Or if the circumference is laid down to a reduced scale, the height of the perpendicular will give the pitch to the same reduced scale.

The pitch of a propeller may be taken by measurement, and calculated from as follows:—

Set off any two points on the face of the blade as at Fig. 59, *a-b*, equidistant from a centre line, *c-d*. In Fig. 60 draw a horizontal line *d-d*, and on it erect a perpendicular, *d-a*, the length *d-a* being equal to the height from the point *a*, Fig. 59, plumb to the face of the boss, measured from a straightedge laid across the boss face. With the chord length *a-b* in Fig. 59 measured along the blade face, set off a length *a-b* in Fig. 60. Measure up the distance *d-b*, Fig. 60, equal to the plumb height

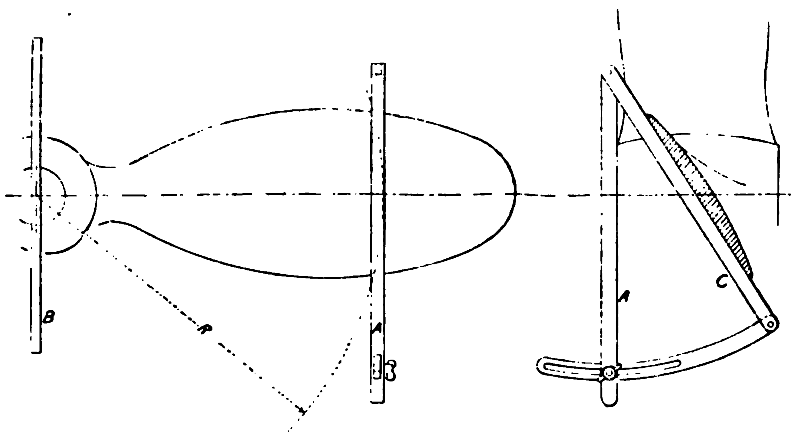


Fig. 58.—Pitchometer.

from the point *b*, in Fig. 59, taken from the straightedge laid across the boss. Carry along a horizontal line, *a-c*. Then *c-b* will represent

the difference in height of the points *a* and *b* in Fig. 59, taken on the chord length *a-b*. Take the radius *c-a* or *c-b* in Fig. 59, and strike an arc, Fig. 59, *a-d-b*, from centre *c*, corresponding with a chord length equal to *a-b* in Fig. 60. Take the length of this arc, and measure it on a horizontal line, set up the length *b-c* perpendicularly at one end, equal in length to the height *c-b* in Fig. 60. Then the length of the base line is to the perpendicular as the circumference of the circle described with the radius *c-a*, Fig. 59, is to the pitch of the screw propeller.

A neat graphic method of obtaining the pitch

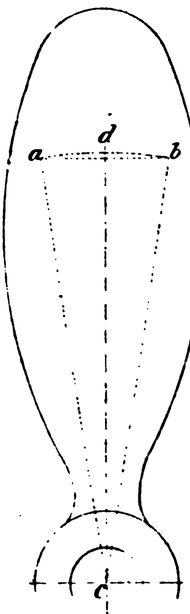


Fig. 59.

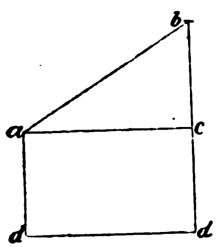


Fig. 60.

Measuring Pitch of Propeller Blades.

of a propeller, without involving any calculation, is as follows. A circle is struck on the boss as large as possible (the hole being plugged for the centre), and divided into twelve equal parts. A straightedge is set on the centre, first to one-twelfth part division, and then to the next adjacent, and at each location the depth is measured from the straightedge to the face of the blade. The difference in depth gives the distance corresponding with the angle of the blade at the radius where it is measured. The pitch of the propeller in feet will be equal to the distance just measured in inches. That this is true can be easily seen, because the portion of the pitch taken corresponds with the twelfth part of the circumference of the boss. This can be demonstrated thus:—Mark off the twelfth part of the circumference of the boss as a horizontal, and at one end erect a perpendicular equal in length to the portion of the pitch just taken, and draw the diagonal. Continue the horizontal to the entire length corresponding with the circumference, and continue the diagonal. A vertical connecting the two will give the pitch of the propeller.

Examples of Propellers.—Figs. 61 to 63 illustrate propellers made by the Pallion Engine Works of Messrs Wm. Doxford & Sons, Ltd.

Fig. 61 shows a solid right-hand propeller, in cast iron, 16 ft. 11 in. diameter, and 17 ft. 3 in. pitch. It is shown in relation to the opening in the stern frame. The dimensions of the striking plates are shown, and the cross sections of the blades.

Fig. 62 is one right hand, of 19 ft. diameter, and 21 ft. pitch, the blades leaning backwards. It is of the built-up type, the blades being of bronze bolted to a cast-iron boss, on which the pitch is made adjustable. The taper of the hole is $\frac{3}{4}$ in. per foot. Points to note are the following:—

The boss A, which measures 3 ft. $6\frac{1}{2}$ in. across the flats, and 3 ft. 9 in. in length, is recessed on the faces to receive the flanges which terminate the blades B. The metal is also lightened, not only to reduce weight, but to ensure a sounder casting, *i.e.*, less liable to draw in the thicker masses. The details of the fitting of a flange are shown at C. The stud holes are arbored, and provision is made by slot holes for adjusting the pitch to the extent of $\frac{3}{4}$ in. difference in the diameter of a stud and the length of its slot hole in the boss. A stud enlarged is shown at D. These are of Lowmoor iron. The nuts are of gun-metal, of box form, to protect the studs, and they are prevented from slackening back by a small set-screw tapped through the end of the nut into the end of the stud, the thread being left handed.

At E is shown the fitting of a hollow gland to protect the neck of the shaft from the action of the sea water. The ring E is fitted in halves and bolted together through its lugs, encircling the shaft, and it is attached to the propeller

ss with eight tap bolts *a* of Muntz metal, in. in diameter. An indiarubber ring, *b*, is ted in a recess in the boss, and the space closed between it and the ring E forms a llow chamber. It can be filled through a le, *c*, on removal of the screwed plug. To ssen risk of fracture of the boss, it is bonded th two rings of wrought iron, F, F, shrunk on. The sections of the blades are shown adjacent one of the blades. Ample dimensions are

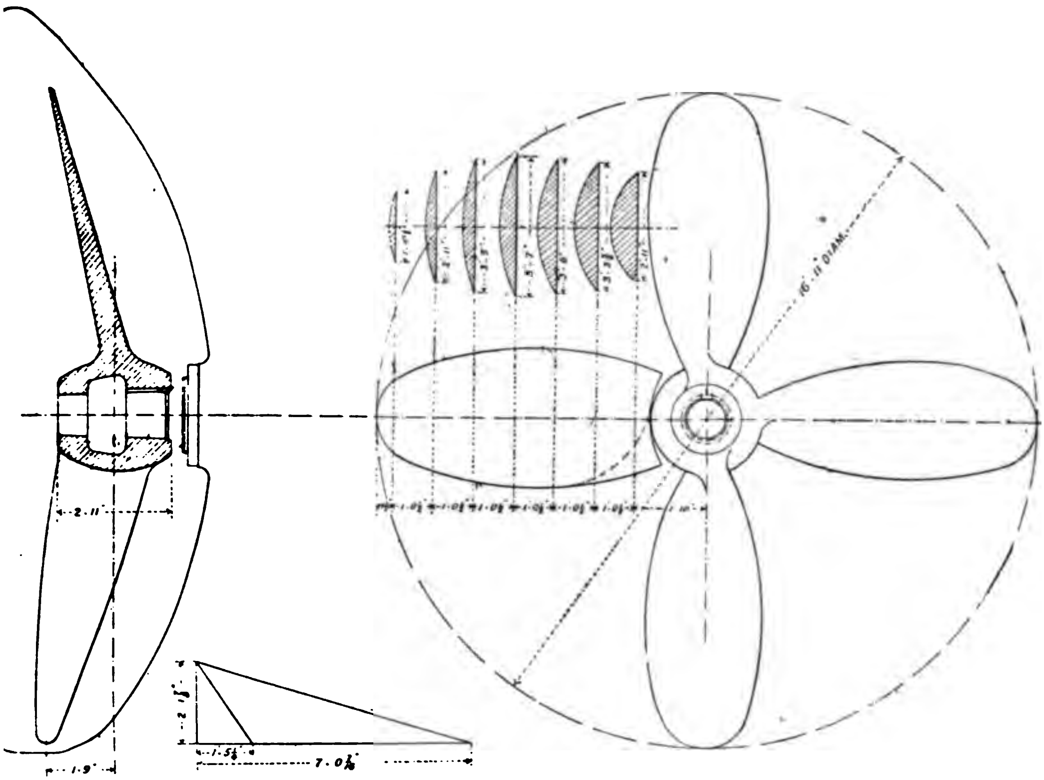


Fig. 61.—Solid Propeller. (Pallion Engine Works.)

en on each section. The dimensions are en, with the angles for the guide plates for iking the mould by.

Fig. 63 shows a propeller having the blades cased in brass to prevent corrosion. The ss A is of cast iron, the blades B of cast steel. e diameter is 18 ft., the pitch 19 ft. The nges of the blades abut against the boss es, but a stud registers the two, so that the esses are not thrown entirely on the bolts. e bolt holes are shown at C, and provision is made in slot holes for adjusting the pitch. A stud is shown at D. It is of Yorkshire iron. The cap nut, of brass, is secured with a steel tap bolt.

The brass covering plates are $\frac{3}{16}$ in. thick. They extend up to 6 in. from the flange on the front side, and 9 in. from the flange on the back side. They are attached with $\frac{1}{2}$-in. screws, the heads of which are riveted over, as shown in the enlarged section at E.

Moulding Screw Propellers.—There are three ways in which this work is done: by sweeping up in loam, by moulding from cores, and from a pattern. The first is adopted for large castings, the second for those of medium or small dimensions, and the third for the same, and for repeat work.

Loam Moulds.—These are built on a suitable plate, Figs. 64 to 69, A, either of circular, or segmental form, in the middle of which a striking bar is pivoted. Divisions corresponding

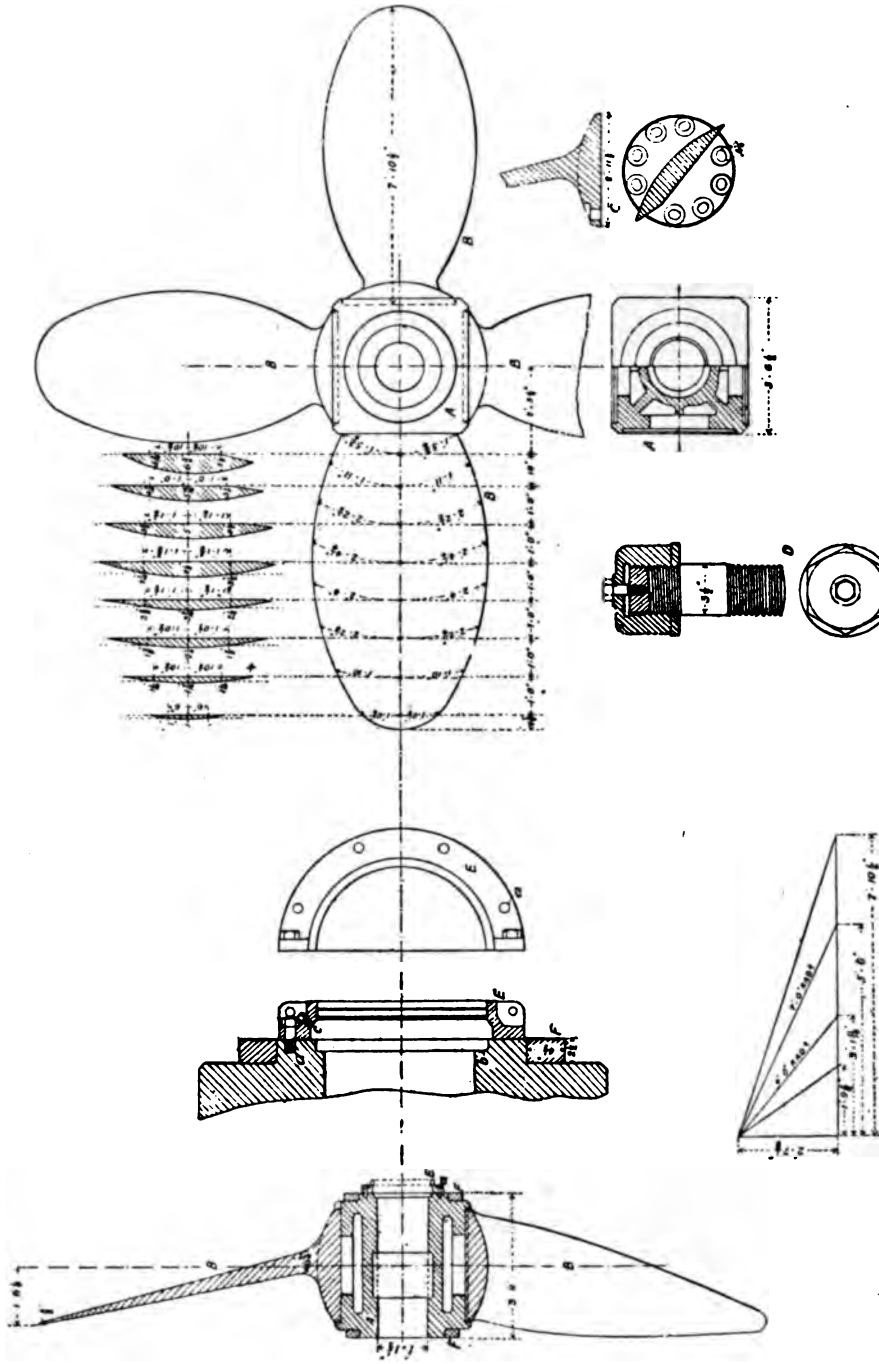


Fig. 62.—Built-up Propeller. (Pallion Engine Works.)

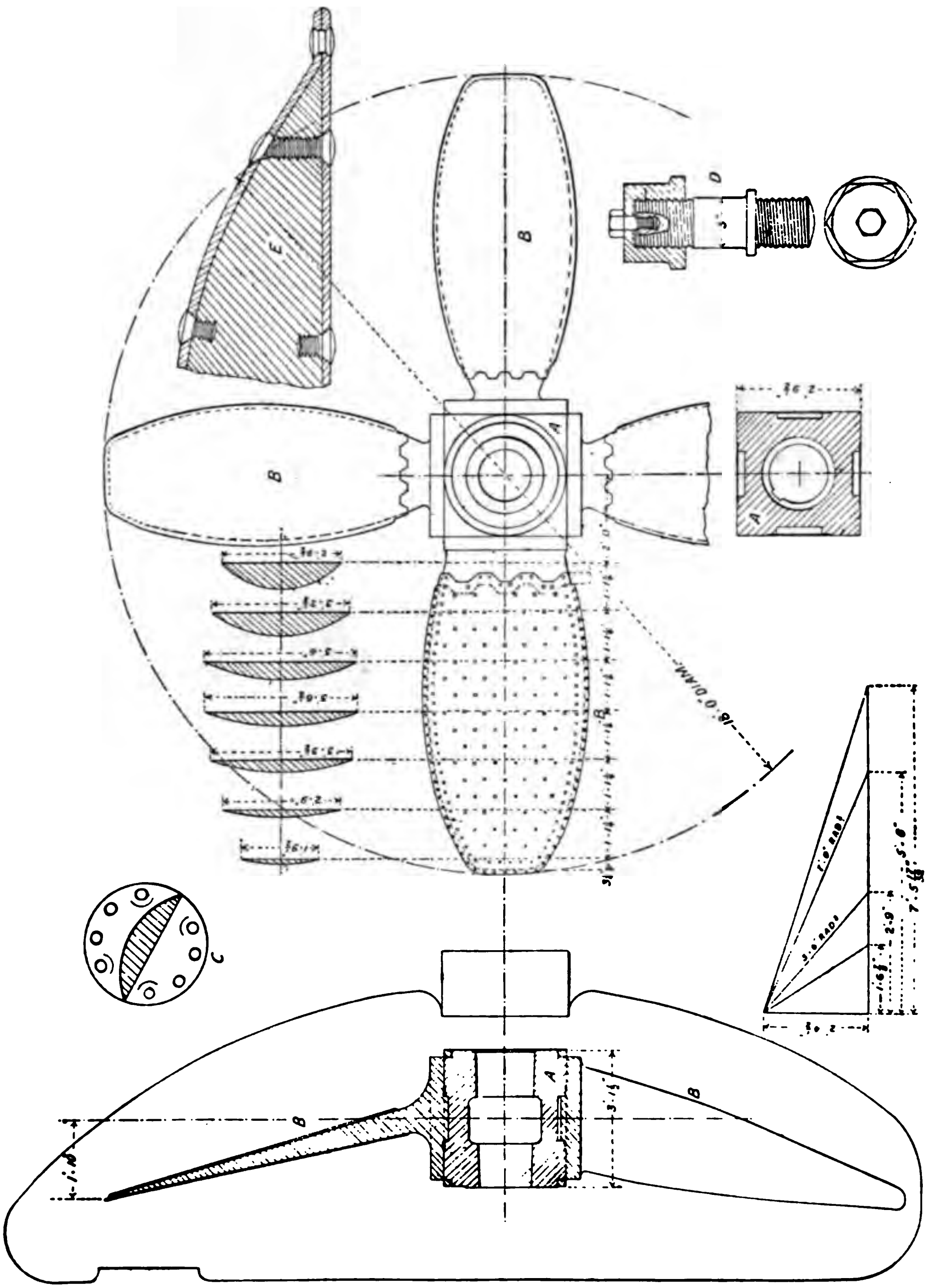


Fig. 63.—Propeller having Blades Sheathed in Brass. (Pallion Engine Works.)

with the number of blades are made on the face of the plate, and on these, sloping beds have to be bricked up rather larger than the blades.

The plate is generally levelled in a pit, and

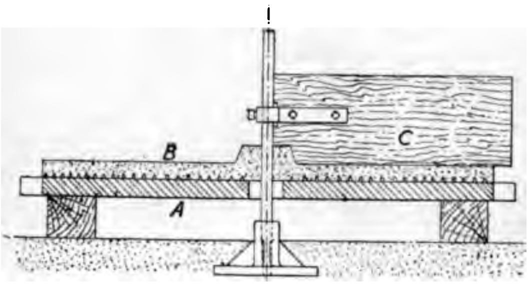


Fig. 64.—Sweeping Bed.

the work dried *in situ*, but it may be blocked up on the floor, and lifted bodily and run into the stove for drying, this being suitable when the dimensions are not very large.

The first stage of the work is to sweep a thickness of loam, Fig. 64, B, over the face of the plate A, with a board, C, to form a level bed on which to build the subsequent work; and a central stand generally on which to build the boss. This is dried, and then the locations of the blades are marked out on it, Fig. 65, starting from one edge of each blade equidis-

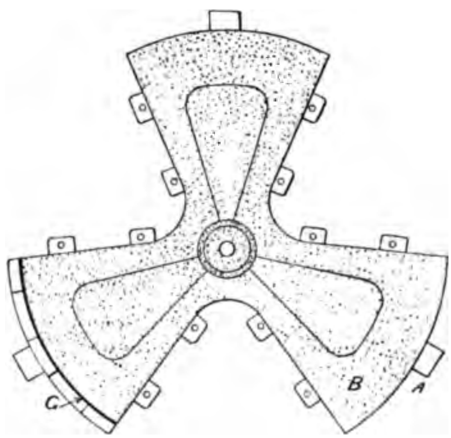


Fig. 65.—Plan of Bed marked out.

tantly from each other. Following this first stage comes the sweeping up of a dummy boss, unless alternatively a wooden boss, or one in loam is built up to encircle the sweeping bar. A loam boss can be swept up as in Fig. 66, D, with a board, E, and dried. Or against a board as in Fig. 67. Hay bands are wound round the bar, and the loam daubed on them. The bar can be slid out endwise, and the hole left encircles the bar which is used to strike up the blades. The loam boss is thus used precisely as a wooden one is. If the boss pattern is swept up in place with a board attached to the striking bar, Fig. 66, this may be done at the present stage, or after the

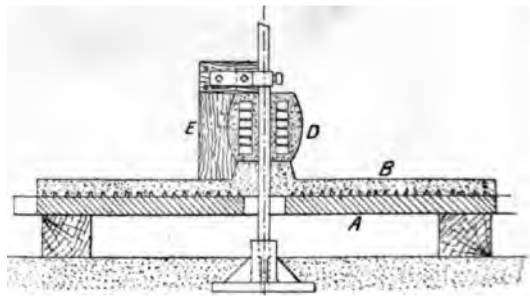


Fig. 66.—Sweeping Boss.

beds have been prepared for the blades. If afterwards, a space must be left between the beds and the boss to allow room for the boss board to be swept round. But if the boss is swept as in Fig. 66, a little space between the termination of the bricks next the boss, and the boss will be left to be made good with loam. The subsequent operations are as follows:—

The angle of the blades is obtained from a

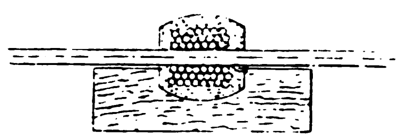


Fig. 67. – Sweeping a Boss.

templet, G, Fig. 68, which controls the movement of the sweeping board. This is either of sheet iron having its edge cut to the angle, and bent, or is framed of wood. As the surface of a screw blade is composed of radial planes, the working edge of the sweeping board is a straightedge, swept over the inclined edge of the templet. The weight of this is often counterbalanced by a weight suspended from a cord over a pulley.

Sometimes a plain straightedge is used, and then two templets are required, one being next the boss.

The brick-work, Fig. 69, H, is built up over as many areas as there are blades, whether three, or four, and is large enough to leave room for jointing the copes. It is roughly triangular in outline, and is sloped approximately to the angle of the screw blades, Fig. 70. It is built of a hollow form to enclose a large quantity of cinders, and a space is left as just stated next the boss for a thickness of loam, the allowance for which, together with that to go on top of the bricks, between them and the edge of the board may range from 1 in. to $1\frac{1}{2}$ in. The cinder area will have been first covered over with loam bricks, or lumps of broken loam. Plenty of thickness is left at the joints, and the loam used is coarse and stiff. After the whole has been allowed to stiffen for a few hours, the final sweeping of the faces is done with finer loam.

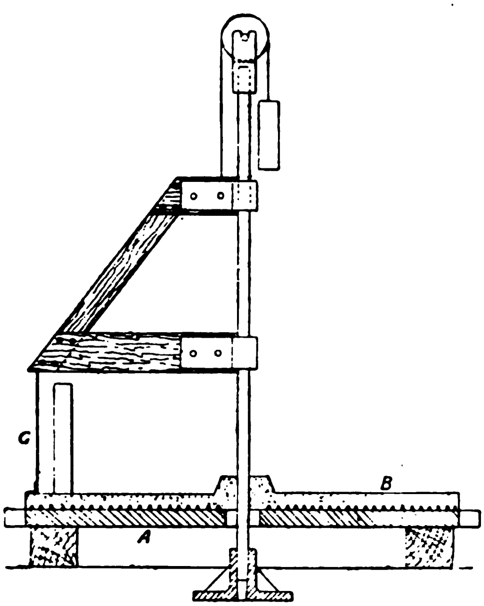


Fig. 68.—Shows Method of Striking Sloping Faces.

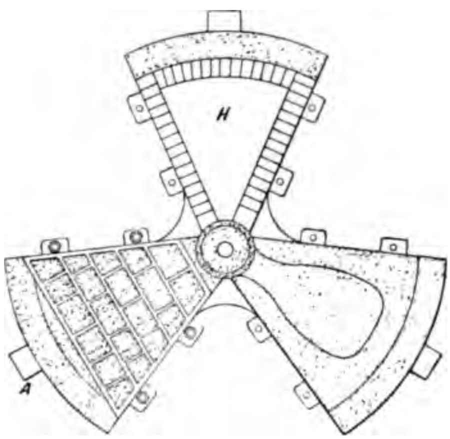


Fig. 69.—Plan of Bricks and a Cope.

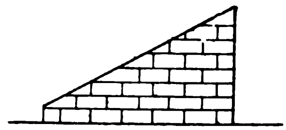


Fig. 70.—Elevation of Bricked-up Bed.

The convex faces of the blades are obtained by means of the templet strips, the development of which is given on the shop drawings, Figs. 61 to 63. These are cut in wood (sometimes in lead), and laid on, and prevented from shifting by nails on each side going into the loam, or they are dowelled on the faces which have been just swept up. The locations of the templet sections can be quickly marked by using an arrangement which embodies the principle of the long toothed gauge. A block is fitted to slide radially along the striking bar, and in a groove on one face of this a vertical gauge rod is slid up and down to accommodate its lower pointed end to the slope of the blade. Being moved by the central bar in an arc of the circle the lines are drawn concentrically.

By the lines thus drawn on the face of the swept-up bed, the templet strips are laid, and secured in place, as stated, with nails driven in on each side. The spaces are filled up with sand, and strickled off, and dried and dusted with parting sand in readiness for the laying on and loaming of the tops.

The tops are next rammed on the convex faces so prepared. They are open grids, formed of bars cast or bolted together, making a structure which follows roughly the outlines of the blades. They may be cast solidly as in Fig. 69, or built up with separate ribs, Fig. 71. The backs of the blades having been dusted with parting sand are covered with a coat of loam. The grids have the spaces filled with

loam blocks set in loam, and the faces are loamed over and laid on the coatings spread over the convex faces, and pressed down until

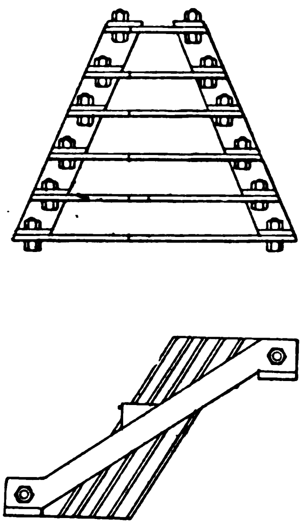


Fig. 71.—Cope Grid.

the loam amalgamates. Then they are dried and lifted, the moulds parting at the sand joints. The dummy strips and sand forming the pattern blades are removed, and the faces below cleaned, blackened, and dried, the copes being treated similarly, and the mould put together for pouring. In some cases a ring encircles and lies on the tops, being weighted to keep them down, Fig. 72. Plenty of sand is shovelled and rammed around the bars and tops. Pouring is done in the boss. In other cases the copes are bolted down to the bottom plate, through lugs, in the manner shown in Fig. 69.

Pattern Blades.—One way of making these is to sweep up a bed as though for a mould, because it is an easy way of getting the exact shape of the flat faces. On this the pattern blades are fitted with planes. When they make close contact their faces are accurate, and from these it is easy to work the convex faces.

More often the pattern blades are made by building up in thicknesses of stuff. In this way a single blade can be worked and put in a core box. Or its boss can be made complete and bored to fit over a central bar, around which it is shifted to three or four equidistant localities in succession to be rammed up.

Patterns are built up in the following manner:—A diagram of the screw can be made by the method of equal division, and from this the angle at the tip, and that next the boss can be obtained. Or the length of the circumference, and the pitch can be marked out as a right-angled triangle, and the angle at the tip and at the boss obtained by marking diagonals at the latter corresponding with the length of the circumference of the boss. An end view of the blade is now drawn, giving the angles at tip and boss, and the depth divided into any convenient number of equal parts ranging say anywhere between $\frac{3}{4}$ in. and $1\frac{1}{4}$ in. The edges of the strips are cut as guides for subsequent working by after they have been glued up.

In building up strips to form blades, the face from which work is begun is the flat face, against which the thrust is taken. This is radial. Hence the corresponding edge of each strip of which the blade is built up is planed straight, and set

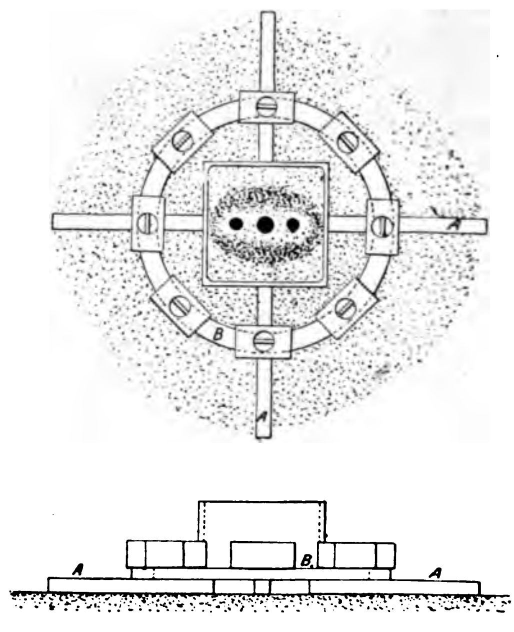


Fig. 72.—Plan of Closed Mould.

radially in spiral staircase fashion. Enough stuff is left in breadth from which to cut the blade thickness. The radial edges are set from the drawing to give the correct angle, and are

superimposed, so that when the square edges are cut away, and the surfaces reduced down to the joints, the flat face of the web will be correctly developed. Afterwards the shape of the other face, and the correct sections are imparted by cutting them by templets.

The number of blades in a screw only affects the methods of building. The radial edges are set similarly in either case. But with two blades, the opposite blades, with the boss, are in continuous pieces. With three blades, joints are made at the boss end of 120° of angle. With four blades, the strips cross with half-lap joints at the centre.

A single pattern blade rammed in a core box, and the cores laid in their proper relations in a circle, is a method which resembles so far the methods by which the arms and bosses of a flywheel are often made in cores. The plan angle of the boss segment is obtained by blocking fitted in the box, as in flywheel cores. The cores are made in two, top and bottom, built on grids, and divided round the edges of the pattern blade.

Fig. 73 shows a core box for making a four-bladed propeller by means of cores. After a core has been made, the box is parted and

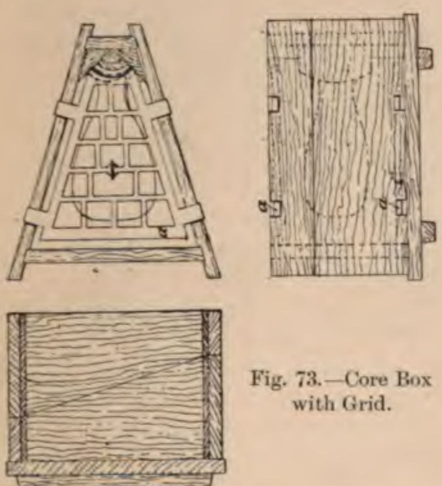


Fig. 73.—Core Box with Grid.

removed from the core and the latter dried. Cleaning up and blackening follows. Then the cores are laid out equidistantly on a level bed, and all rammed round with sand to prevent them from shifting, Fig. 74. A plain cope is rammed and laid over, and the pouring basin and ingates made over the boss.

Screw Shaft.—The propeller shaft of a

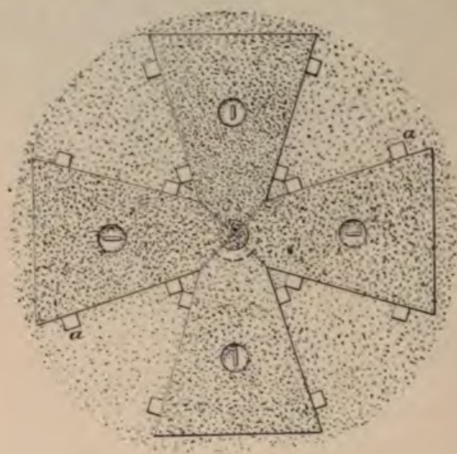


Fig. 74.—Plan of Closed Mould.

vessel. It passes through and is enclosed by the stern tube. It is made in convenient lengths, and united with solid flanged couplings. The propeller is attached to a tapered end, and secured with a nut. Endlong pressure is taken by thrust collars, and bearing blocks. Shafts which were once made solidly of wrought iron, are now of fluid compressed steel, and of hollow sections.

Screw Thread Milling.—This is an operation which has been developed in a high degree, largely in consequence of the demands for accurate worm gears for electric drives. But it has been extended to include long screws as nearly square-threaded as can be cut, suitable for lead screws, rock drills, thrust screws, &c. The advantages of this method of cutting over that done in the lathe with a single-edged tool are that less time is required, and a less skilful operator, the work may be made interchangeable, and that one traverse only is necessary.

Many years ago screw threads were occasionally milled in the screw-cutting lathe, using an overhead motion for rotating the cutter. But this is only a makeshift device, and as such was adopted only when great accuracy was imperative. But the first machine made by which long screws could be milled commerci-

ally, is apparently that invented by H. Liebert, and made by John Holroyd & Co., Ltd. From the original type numerous forms have grown, suitable for all classes of thread and screw cutting. Some other firms have also made machines designed more especially for the work of cutting worms. We will now note the leading characteristics of this important group of machines which have become essential in many shops.

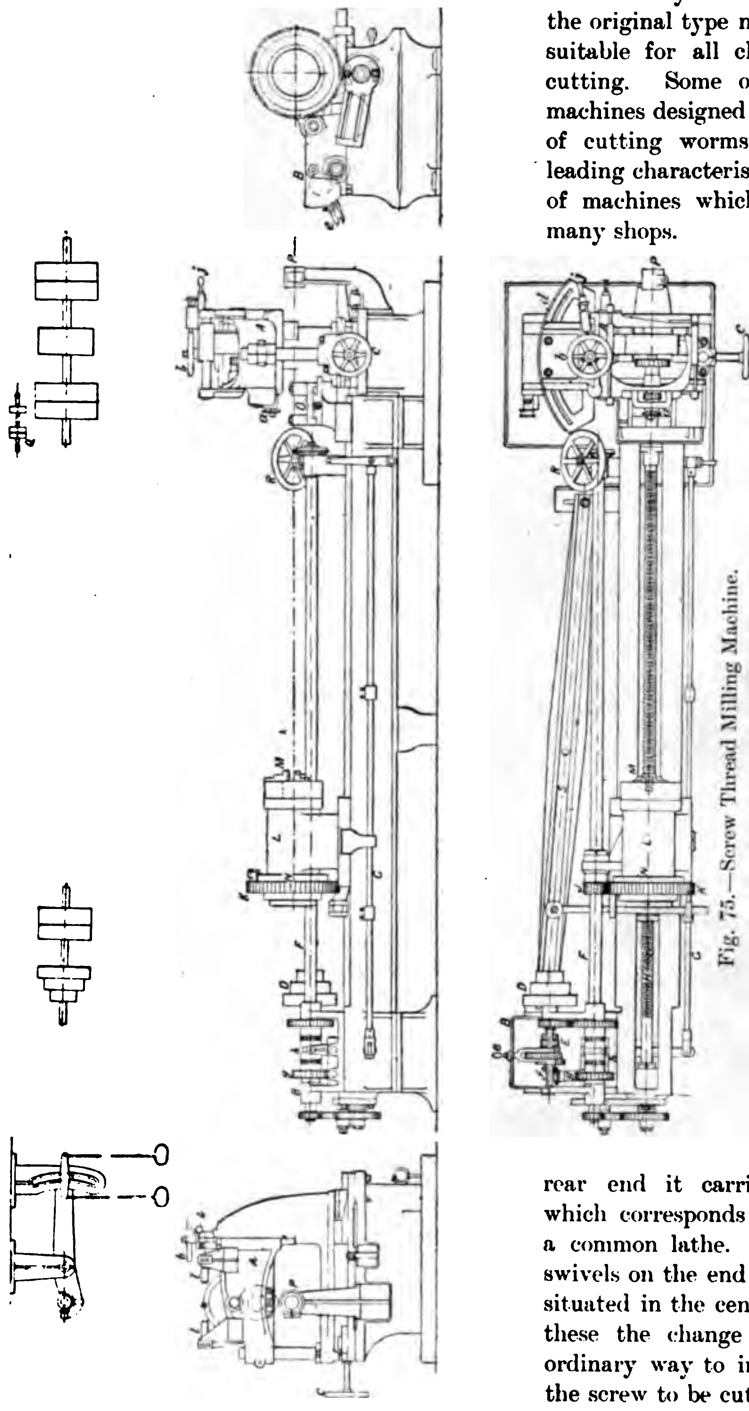


Fig. 75.—Screw Thread Milling Machine.

The Liebert Machines.—These are built after two principal models—one may be termed the lathe bed type, the other the milling machine design.

In the lathe type, a long bed is carried on two or three legs, one of which to the right, Fig. 75, is utilised as a cabinet. Over this is the cutter headstock A with its slides. At the other or left-hand end, a fixed head or gear box, B, carries the feed gears connected to the feed spindle, and by change gears to the lead screw which runs along the centre of the bed. Between this box, and the cutter headstock is a carriage and head L movable along the bed carrying the work spindle, which is hollow, and through which the bar to be screwed passes. A two-jawed chuck on the spindle nose grips the work. The feed rod is splined. At the rear end it carries the first change wheel which corresponds with the mandrel wheel of a common lathe. A quadrant or swing plate swivels on the end of the lead screw, which is situated in the centre of the bed, and between these the change gears are set up in the ordinary way to impart the required pitch to the screw to be cut.

The cutter headstock A has provision for

effecting all the movements of the milling cutter. The cutter *a* is carried by a hardened steel spindle running in conical bearings, and driven through gears from a cone pulley, with one, or two speeds. The headstock has provision by hand-wheel *b* for adjustments in the vertical direction, and by hand-wheel *c* in the transverse direction, the latter to bring the cutter over the centre of the work. The spindle can be swung to any angle up to 25° with the screw which is being milled, and to either hand, so that right or left hand threads can be cut. A scale is furnished at the back, *d* for setting the angle by. The angles are found by means of an instrument called an angle finder, which is described at the end of this article, and which is supplied with each machine.

The feed is effected from a stepped cone pulley, D, driven from its own countershaft seen above, Fig. 75.

D drives a pinion which engages with either one of five gears in a nest, E, through the feed change lever *e*. Thence mitre gears *f* drive the worm gear *g* on the splined feed shaft F. A clutch, *h*, is fitted by which the feed is automatically knocked out by the rod G with dogs in front of the bed. There is also a set of quick reversing wheels.

The feed rod F drives the change gears to the lead screw H, and also the splined gear J, which engages with the gear K at the end of the hollow headstock spindle in the traversing head L. As both the rotary and forward feeds are obtained from the shaft F, a uniform feed is secured for the various pitches, and diameters of work. A chuck, M, is secured to the front of the hollow spindle to grip the work. The spindle is 8 in. diameter and has a hole $6\frac{1}{4}$ in. diameter through it. It is driven from wheel K, through a driving or latch plate N keyed on the spindle, the gear wheel revolving on an extension of this plate. A latch is fastened to the wheel, and lies in one of several slots cut on the edge of the plate. A number of slots are provided for cutting multiple-threaded screws without the trouble of marking positions on gears.

The work is supported directly against the pressure of the cutter on a stay, which consists of a pair of horizontal slides O, moved in and out by a right and left hand screw. Between the two pairs of vee blocks, either an ordinary compound lathe tool slide, or a profiling cutter headstock can be placed. A pump for lubrication is supplied, and a separate countershaft, Q, for driving it. R is the hand-wheel for rapid adjustment of the traveller head L. S is a swivel plate for a compensating arrangement. *j* is a handle which provides a quick withdrawal to the cutter head. *k* is a screw which provides fine adjustment for depth of cut; *l*, *l* are belt guide rollers. This machine will take work up to 6 in. diameter and 5 ft. long at one setting. There is a stay, P, for long bars. The pitch may be varied from $\frac{1}{16}$ in. to 2 in.

One machine by this firm is designed for large drums and worms up to 12 in. diameter. In this, the cutter headstock is carried on an extension bracket and standard at one end of the bed. Except in details, rendered necessary by the more massive character of the work, the machine follows the lines of the lathe design.

The type of machine just described will take bars of any length through the hollow spindle. But for short screws regularly done, the pillar milling machine type is designed. In this the pillar carries the headstock on top, and the knee carries the work slides. The cutter spindle passes through a hollow shaft on which the stepped driving cones are mounted. The outer end of the driving spindle is carried in a conical bearing on an outer support which is attached to the overhead arm. In order that this support shall be always kept close to the cutter, a rack and pinion are provided for adjusting the spindle, the outer support, and the top arm horizontally.

The knee receives the carriage mechanism, comprising the swivel and cross slides, the swivel for setting to the angle, corresponding with the pitch of the thread, and the cross slides for bringing the work centrally under the cutter. The carriage mounted on the swivel slide has a spindle and chuck for holding the work. At the opposite end of the spindle is mounted the first wheel in the change gear train. The gears are connected through a quadrant plate to the lead screw, having its bearings on o e side of the swivel slide. This

connection is made through a wheel on the end of a splined shaft in the centre of the slide, the giving six changes through worm gearing and mitres to the splined shaft. The gears are

Fig. 76.—Screw Angle Finder.

wheel being of equal size with that on the end of the work spindle. The feed to the work is transmitted from a double set of cone pulleys, released by a knock-out motion when the thread has been cut up to the length required.

The cutters used on these machines have

teeth on three edges, and are usually either $2\frac{3}{4}$ in. or $3\frac{1}{4}$ in. diameter, each size being made from $\frac{1}{16}$ in. to $\frac{1}{2}$ in. wide. For worms and Acme threads a special range of cutters in high speed steel is made. Besides these, cutters for half-round threads, and the commoner Whitworth threads are supplied.

Messrs Holroyd have a screw angle finder designed by Mr Vincent Gartside, by which the angle to set the cutters by can be read by inspection. It is shown to a slightly reduced scale in Fig. 76. The diameters of screws in inches are given around the upper part of the fixed scale, and range from $\frac{1}{8}$ in. to 10 in. The leads of the screws in inches are given around the upper part of the rotating scale, which is pivoted in the centre of the outer fixed scale. These range from one to eight threads per inch to the left, and from 1-in. pitch to 10-in. pitch to the right. Each of the major divisions is conveniently subdivided. The *lead* it may be stated is the equivalent of the pitch in a single-threaded worm, or screw. But in multiple-threaded worms it means the pitch of one thread—the *axial* pitch—as distinguished from the pitch measured from centre to centre of the adjacent multiple threads. In a three-threaded worm the lead would be three times the pitch of adjacent threads.

Looking at the instrument as it stands in zero position, it appears that for any one combination shown, the angle indicated by the pointer is the same, $17\frac{2}{3}$°. By turning about and setting, say, 1-in. lead opposite 2 in. diameter, the angle required is 9°. And the same for two threads on 1 in. diameter, or a 2-in. pitch on 4 in. diameter, and several others. Setting four threads per inch on 1 in. diameter, the angle is $4\frac{1}{2}$°. And the same with two threads on 2 in. diameter, or eight threads on $\frac{1}{2}$ in. diameter. A long lead or pitch of 3 in. on 1 in. diameter gives $43\frac{1}{3}$°.

The Pratt & Whitney Machine.—The thread milling machine designed by the Pratt & Whitney Co. is built on original lines, is very compact, and in the various sizes and modifications in which it is manufactured will cut all kinds of threads, and worm and spiral gears. In the whole range of six machines made, diameters up to 12 in., and lengths up to 132 in. are included. The smaller machines are mounted on a cabinet base, surmounted by a pan which completely surrounds the working bed. The larger ones are of lathe design, that is with a large bed mounted on legs.

The construction, Fig. 77, Plate V., is as follows:—The head and tail block are carried on a flat way at the front, and on a single vee at the back of the bed. The work is gripped by a collet in the headstock spindle, and on a centre in the tailstock. Or, in the case of work larger than the centres will take, the tailstock is hollow, and fitted with bushings to pass the work through. The carriage of the cutter head rests on flat ways at front and back of the machine, and is gibbed at the rear. The arbor of the milling cutter is mounted in a head which is connected to the cross slide of the carriage by trunnion bearings, which permit of setting the cutter to any angle required for threads of various pitches. The centre of the cutter is always in the same horizontal plane as the screw to be cut. Tables are provided for all angles required for standard pitches, one of the trunnions being graduated. To set the correct depth of cut, there is a micrometer head on the cross-slide screw of the carriage. The work having been prepared to size elsewhere, and put in the machine, the cutter is brought up to the cross-slide screw, until one tooth of the cutter is brought into contact with the work, when the micrometer is set to zero. The carriage is then run along until the cutter clears the end of the work, when the cutter is fed inwards by the micrometer cross-feed screw to the correct depth corresponding with the pitch, for which a table is provided, and the cross slide is then clamped in readiness for cutting.

The pitch is obtained by change gears and lead screw, the latter being within the bed. Stops adjustable on a rod knock out the cut at a predetermined point, and in either direction, right or left. The carriage can be run along independently of the change gears by turning a crank, operating worm gear at the back of the carriage, which rotates the nut of the lead screw. The cutter can thus be set to begin the thread at any locality. Or it can be reset at its proper place, if its withdrawal for any purpose should

be necessary. When the carriage has been located, the nut is locked in position by a lever, so that no movement of the carriage can take place except by the lead screw. The lead screw has six threads per inch, but for cutting threads over 2 in. pitch, and spiral gears, a coarser screw is recommended as a duplicate, which can be changed in ten minutes. A metric lead screw can be supplied, or translating gears for metric to English threads, or *vice versa*.

Belt Driving System.—Both the cutter head and the feed are driven by one belt of $2\frac{1}{2}$ in. width. A three-grade cone pulley is mounted on the head of the splined driving shaft which drives the head spindle through the various ratios of gearing in the feed gear box, and drives the cutter head through the vertical telescoping shaft and bevel gears. This arrangement provides three speeds for the cutter, to compensate for different diameters of cutters and the varying quality of stock to be milled, and also reduces the liability to damage of work or cutter by the failure of a belt. The pump and quick return for the carriage are driven by separate belts.

Spindle Speeds.—The necessary variations in spindle speed are obtained by means of a gear box at the rear of the machine. By shifting two levers, one of which has six positions on its dial, and the other, three, eighteen changes of speed are obtained in geometrical progression for each of the three speeds of the driving pulley. This gives a total of fifty-four changes of speed available for either the spindle drive or the lead screw drive.

A reverse clutch, operated by a knob at the rear of the gear box, makes the entire range of speeds available in either direction, for right or left hand threads, as may be necessary. These speeds will be found sufficient to meet all requirements from fine threads on screws of $\frac{1}{4}$ in. in diameter to work 6 in. in diameter.

There are two changes on the countershaft, and two on the two stepped friction cone on which the main driving belt runs.

Though the spindle is driven in doing ordinary work, yet when threads of steep pitch, say of 1 in. lead and upwards, have to be cut, the driving can be done on the lead screw, backwards, as turners do in cutting steep pitches on common lathes. The sixty-four changes just named are available alike on lead screw and spindle.

The method of indexing for cutting multiple threads and spiral gears is done by means of a compound spindle, comprising an outer hollow spindle embracing an inner hollow spindle. The first carries the driving mechanism, and the spindle gear, the second the nose piece and collet for gripping the work, and also a notched index ring with forty-eight notches; but index rings up to sixty notches are supplied. A pawl on the outer spindle engages with the notches on the inner one, and locks the two together. To index for a given thread the pawl is released from the notch in which it happens to be engaged, and the inner spindle is turned through such a fraction of a revolution, measured on the notches as 1 is of the multiple thread (or the number of teeth in the gear to be cut), and the pawl dropped in place again.

The cutters used are staggered to right and left, that is, each tooth with one exception has but one cutting edge, alternating with its fellows adjacent. The exception is that of one tooth which is left of full size for the purpose of gauging. The regular gear cutters are employed for spiral threads. A steady rest is provided with bushings to support the smaller screws in opposition to the cutter. The formula for obtaining angles for setting the cutter head by is—

$$\frac{\text{Pitch}}{(\text{Outside diameter} - \text{depth}) \times 3{\cdot}1416} = \text{Tangent of angle.}$$

Figs. 78 and 79, Plate V., illustrate the capabilities of the machines, the first being a double-threaded screw of large diameter, the second a spiral spring, cut from tube.

Internal Threads.—These have been milled for many years in connection with gun work. The work is held in a chuck revolving at the correct speed, and the cutter, also rotated, is presented to the bore at a proper angle, being also fed along. The principle is embodied in a special internal machine built by Messrs Holroyd. The cutter spindle bearing is contained in a swivelling quadrant plate, which may be tilted to various degrees of angle. The Pratt & Whitney machines are also adapted to internal

Fig. 77.—Screw Thread Milling Machine. (The Pratt & Whitney Co.)

Fig. 78.—Worm Milled on Machine.

Fig. 79.—Spiral Spring Milled on Machine.

To face page 76.

work, by fitting an attachment on the carriage, to receive the spindle of the cutter. Internal milling is well adapted to short work, such as nuts and collars, especially those having shoulders or blank ends; these would be most awkward to tap, and slow to cut in the lathe.

Screw Thread Gauges.—Screw threads may be measured either in regard to pitch and correct form of thread, or as regards diameter. For the first kind of gauging, flat instruments are employed, notched out to match the thread, so that when applied to the screw, the coincidence or otherwise is visible. These gauges are also used for testing chasing tools, and a number of blades are mounted in a case into which they may be folded when not in use, leaving only the actual blade in use outside. From twenty-two to twenty-six blades, with pitches from four up to sixty are commonly fitted. But to measure diameters some other type of instrument has to be used, and either a micrometer caliper, or a plug or ring gauge must be employed. A micrometer gives precise diameters, the anvil points being made as in Fig. 80, A, to embrace the sides of the thread on one side, and go into the vee on the opposite; the construction of the micrometer is similar to that in Figs. 211, 212, page 193, Vol. VI. Solid plug and ring gauges, Fig. 80, B, C, have means for adjustment in the ring only, the plug being standard. The plain end gives the diameter at the bottom of the thread. The ring is extended into an oblong form, and two screws, *a* and *b*, enable the body, which is split through, to be opened or closed slightly. Plain round pins, *c*, *c*, preserve the lateral truth, preventing the split sides from getting cross-wise through the influence of the adjusting screws. Ordinary ring gauges resemble the plain plug gauges except for the thread; they do not permit of adjustment for fit or wear, as in the case of C. These gauges indicate the diameter, and the pitch simultaneously. Sometimes an extra plain portion is added to the gauge in Fig. 80, B, to give the diameter at the tops of the thread.

Screw Threads.—A screw is a geometrical solid of a definite section wound spirally round a cylinder at equal intervals, forming a continuous ridge. In its essential elements it is referable in mechanism to a right-angled triangle wound round a cylinder. The length of the base of the triangle equals the circumference of the cylinder, its height equals the pitch, and the hypotenuse is the angle of the spiral. The spiral may be inclined to the right, or left,

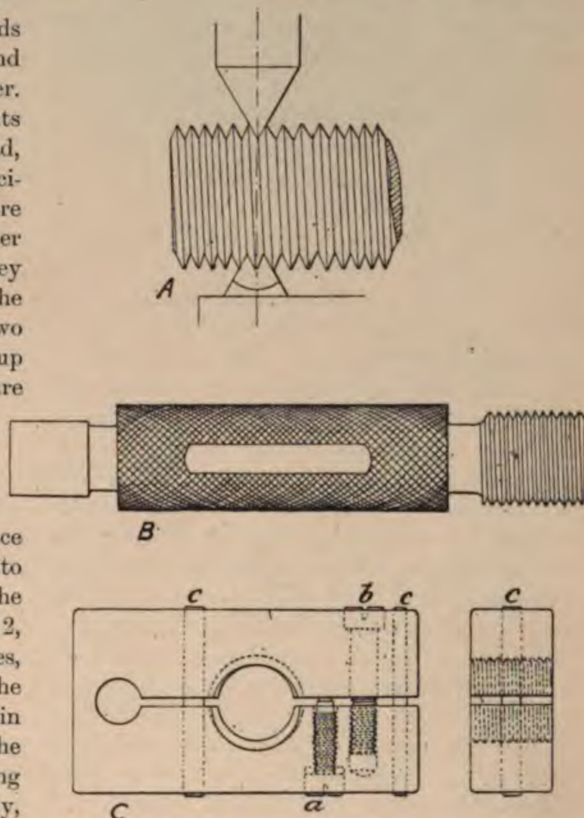


Fig. 80.—Screw Thread Gauges.

giving a *right*, or *left-handed* screw. A pitch remains constant in its successive convolutions, but the angle of spiral, equivalent to the rake of the thread, depends on the circumference of the cylinder, or length of base of the triangle, so that screws of the same pitch will have less *rake* or slope when on a larger than on a smaller cylinder. The *diameter* of a screw is invariably given as that over the extremities or tips of the thread. The diameter of the body or root is dependent on the *sectional form* of the thread, in other words on the proportions embodied in the screw. The *tensile strength* of a screw bolt is estimated on the area of that body, and the *tapping size* is approximately equal to its

diameter. The *depth* or height of a screw thread is that which is measured perpendicularly from the body or root to the tip. This, with the sectional form of the thread determines the strength and durability of a thread, while the pitch or angle settles the power gain.

No formula is of universal application, but screw threads have been settled empirically by a process of collation and averaging of existing forms. The proportions of screw threads may be cited as illustrative of the little aid which theory has afforded. Existing proportions were fixed somewhat empirically by Whitworth without much regard to theoretical considerations. Questions of pitch, of depth, of sectional form, relations of mechanical power, of strength, of durability, cannot be settled apart from practical issues. Each element must be decided in reference to the others, and therefore the Whitworth threads, in common with others are a compromise between the extremes of a very varied practice. Whitworth collected screw bolts from the chief factories in England, and compared and collated and averaged them. The principal ones taken were the ¼ in., ½ in., 1 in., and 1½ in., and a workable mean, avoiding minute fractions, was taken as the basis of the new system of screw threads. In the old screw threads there was no definite relation between the pitch and the depth. The Whitworth constant angle of 55° for all screws provides this proportion, and that was nearly a mean of the angles of the collated screws.

Screw Elements.—The essentials of a screw are the pitch, the depth, and the form of the thread, each of which can be modified without reference to the others. They control the holding power, the strength, and the durability. The pitch controls the mechanical gain, since the thread is a wedge the angle of which depends on the pitch, for a given diameter. The depth of the thread makes for durability, since the larger the area of its surface the longer will it endure under the actions of fastening and unfastening. The form of the thread includes the elements of angle, point, and root, and is the feature around which most differences occur. It is usual to make threads with double symmetrical angles, or vee'd in section, but this is a concession to convenience of manufacture, just as is the symmetrical form of wheel teeth, even though driving constantly in one direction.

The Pitch.—This is determined by the power requisite for closing work, which decides the angle of the inclined plane formed by the thread. A fine thread pitch gives more power for closing, but it is weaker than a coarse one. A square thread affords more power than a vee thread, but the latter is stronger than a square thread of the same pitch. Hence the pitch is affected by the thread section. And though a deep thread has more durability of wearing surface than a shallow one, it weakens the bolt by the greater reduction of diameter at the root of the thread. The pitch, therefore, cannot be considered alone. It is by the averaging of these conditions as embodied in previous practice that good workable screw threads have been designed.

Angles.—The strength of screw threads depends on their angle.

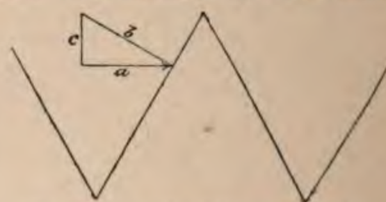


Fig. 81.—Angle of Screw Threads.

The load coming axially as at *a*, Fig. 81, is resolvable into two forces, *b*, normal to the face of the thread, and *c*, perpendicular thereto. The latter tends to burst the nut, and this therefore sets a limit to the angle of screw threads, which in no case exceeds 60°. The frictional resistance and the tendency to burst the nut would become excessive beyond this angle. The angle is a compromise. Steep angles require greater depths of thread, and coarser pitches than those which approach more to the perpendicular. But while deep threads are a cause of weakness, shallow ones lack durability. As a practical compromise the strength is based to a certain extent on the depth of the nut, which is equal in common work to the diameter of the thread. The threads in a nut should be stronger than the cross section of the bolt, so that the bolt would break before the threads would be torn off or strip.

The greatest holding power with the least frictional resistance is obtained when the face of the thread is normal to the axis of the screw (or square), but the strength of the thread to resist stripping is greatest when the face is set at a considerable angle (*vee thread*). The threads for gun breeches combine the two in one (*buttress*), but this device would, for obvious reasons, be quite unsuitable for ordinary mechanisms. The square thread stands apart from vee threads. It is used where much power and direct pressure is wanted, as in presses, and in most screws for machine slides and mandrels, but the pitch of such threads is usually made double that of vee threads of the same diameter in order to secure enough strength to prevent risk of stripping. In cases where clasp nuts have to be thrown in and out, the square thread is modified by being made sub-angular, or by rounding the edges. In the square thread, where the face of the thread is normal to the load, the friction is less and there is no tendency to burst the nut. But for a given pitch it is much weaker than the triangular shape. It is also difficult to cut, and therefore few absolutely square threads are made, but the roots and points are rounded more or less, or the Acme design is substituted. Many lead screws are made thus, but in the majority of instances a slight angle, but less than that of the Acme thread, and a little rounding at root and point are given. The buttress thread is only used for special functions, chiefly for gun breeches. The acting face is perpendicular, thus securing the advantages of the normal thrust, and the opposite face is at an angle of 45°, thus ensuring the maximum of strength. The top and bottom are flattened, or rounded. There is no standard, in the sense that there is with other threads. Another matter of great practical importance is that sharp angles should be avoided. The great objection to the sharp vee thread, which is still in use in the United States, is that the keen roots and points are not obliterated by radii. With regard to the roots, the thread and the bolt section are weakened by the keen angles, and the points are easily subjected to damage by coming into contact with other bodies. This is the only example in which sharp angles

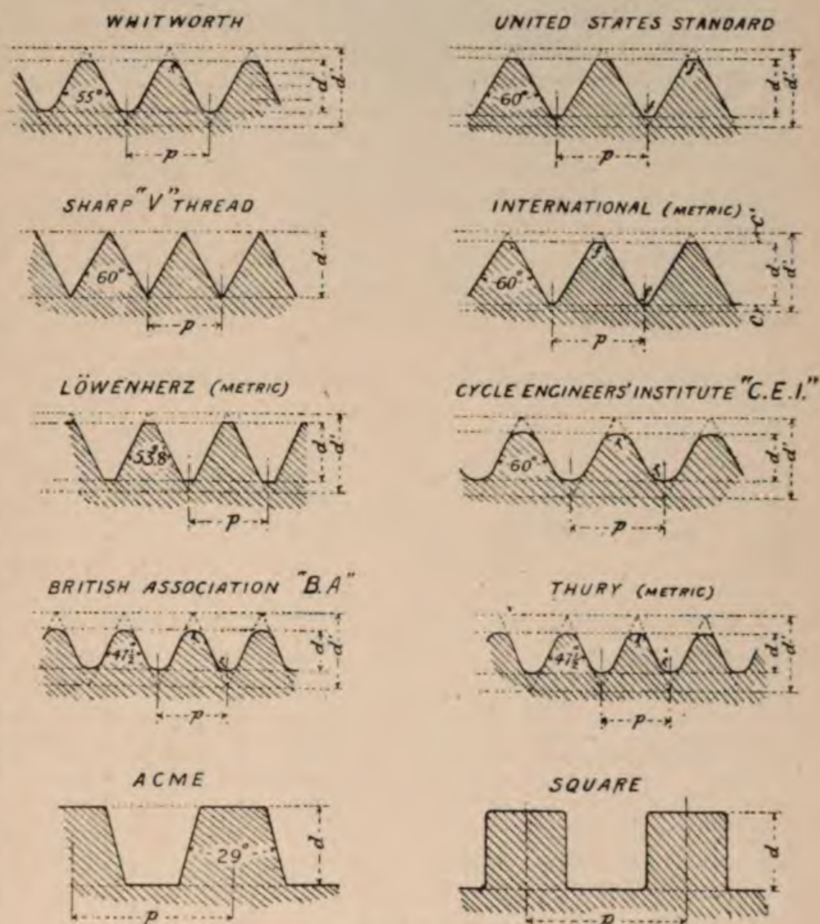


Fig. 82.—Standard Screw Threads.

have been retained in a screw thread. Another matter is that the same system of threads has to be used in cast, and wrought iron, and steels, and brasses, and therefore a system which would be the best on the whole for one material would not be the best possible for others. To take extreme cases, coarser deeper threads are desirable in cast than in wrought iron.

A thread is *single*, when one continuous spiral is wound round a cylinder, as in all common screws used as fastenings. But for effecting rapid movements, two, three, and sometimes four threaded screws are employed, meaning that as many separate spirals are wound round a cylinder, separated by equal distances. The pitch then is not the distance between adjacent screw threads, but that between two, three, or four threads respectively. A *drunken* thread is one in which the threads are wavy and uneven.

WHITWORTH'S STANDARD SCREW THREADS FOR BOLTS.

Diameter of Bolt. Fractional Sizes.	Diameter of Bolt. Decimal Sizes.	Number of Threads per Inch.	Diameter at Bottom of Thread.	Diameter of Bolt. Fractional Sizes.	Diameter of Bolt. Decimal Sizes.	Number of Threads per Inch.	Diameter at Bottom of Thread.
In.	In.		In.	In.	In.		In.
$\frac{1}{16}$	0·0625	60	0·0411	$2\frac{5}{8}$	2·625	4	2·3048
$\frac{3}{32}$	0·09375	48	0·0670	$2\frac{3}{4}$	2·75	3·5	2·3840
$\frac{1}{8}$	0·125	40	0·0929	$2\frac{7}{8}$	2·875	3·5	2·5090
$\frac{3}{16}$	0·1875	24	0·1341	3	3	3·5	2·6340
$\frac{1}{4}$	0·25	20	0·1859	$3\frac{1}{8}$	3·125	3·5	2·7590
$\frac{5}{16}$	0·3125	18	0·2413	$3\frac{1}{4}$	3·25	3·25	2·8559
$\frac{3}{8}$	0·375	16	0·2949	$3\frac{3}{8}$	3·375	3·25	2·9809
$\frac{7}{16}$	0·4375	14	0·3460	$3\frac{1}{2}$	3·5	3·25	3·1059
$\frac{1}{2}$	0·5	12	0·3932	$3\frac{5}{8}$	3·625	3·25	3·2309
$\frac{9}{16}$	0·5625	12	0·4557	$3\frac{3}{4}$	3·75	3	3·3231
$\frac{5}{8}$	0·625	11	0·5085	$3\frac{7}{8}$	3·875	3	3·4481
$\frac{11}{16}$	0·6875	11	0·5710	4	4	3	3·5731
$\frac{3}{4}$	0·75	10	0·6219	$4\frac{1}{8}$	4·125	3	3·6981
$\frac{13}{16}$	0·8125	10	0·6844	$4\frac{1}{4}$	4·25	2·875	3·8045
$\frac{7}{8}$	0·875	9	0·7327	$4\frac{3}{8}$	4·375	2·875	3·9295
$\frac{15}{16}$	0·9375	9	0·7952	$4\frac{1}{2}$	4·5	2·875	4·0545
1	1	8	0·8399	$4\frac{5}{8}$	4·625	2·875	4·1795
$1\frac{1}{8}$	1·125	7	0·9420	$4\frac{3}{4}$	4·75	2·75	4·2843
$1\frac{1}{4}$	1·25	7	1·0670	$4\frac{7}{8}$	4·875	2·75	4·4093
$1\frac{3}{8}$	1·375	6	1·1615	5	5	2·75	4·5343
$1\frac{1}{2}$	1·5	6	1·2865	$5\frac{1}{8}$	5·125	2·75	4·6593
$1\frac{5}{8}$	1·625	5	1·3688	$5\frac{1}{4}$	5·25	2·625	4·7621
$1\frac{3}{4}$	1·75	5	1·4938	$5\frac{3}{8}$	5·375	2·625	4·8871
$1\frac{7}{8}$	1·875	4·5	1·5904	$5\frac{1}{2}$	5·5	2·625	5·0121
2	2	4·5	1·7154	$5\frac{5}{8}$	5·625	2·625	5·1371
$2\frac{1}{8}$	2·125	4·5	1·8404	$5\frac{3}{4}$	5·75	2·5	5·2377
$2\frac{1}{4}$	2·25	4	1·9298	$5\frac{7}{8}$	5·875	2·5	5·3627
$2\frac{3}{8}$	2·375	4	2·0548	6	6	2·5	5·4877
$2\frac{1}{2}$	2·5	4	2·1798				

Standard Threads.—The number of threads which have been used on a sufficiently extensive scale to merit the appellation of "standard," may number from fifty to sixty.

The Whitworth Thread.—This (*see* Fig. 82) is of the same section for bolts, and gas tubes alike, but the threads are finer for the latter. It is, as stated, an averaging of the threads which were in existence previous to Whitworth's efforts at standardisation. Sir Joseph Whitworth went to the bottom of the subject, attacking the problem both from the theoretical and the practical aspects, the theoretical in order to best fulfil the conditions demanded in a screw bolt, the practical in order to interfere as little as possible with the threads then existing.

With regard to the angle of the screw thread, 55°, this was selected as a mean of the variations present in 1-in. screws tested by Whitworth. This angle is constant in all

WHITWORTH'S SCREW THREADS FOR GAS, WATER, AND STEAM PIPING.

Note.—The diameters for pipes as given below, in columns 2, 3, and 5, are those established by the Engineering Standards Committee for British Standard Pipe Threads, 1905. Those given in columns 4 and 6 are the original Whitworth diameters.

Nominal Bore of Tube.	Approximate Outside Diameter of Black Tube. 2.	Diameter at Top of Thread. B.S.P. Thread. 3.	Diameter at Top of Thread. Whitworth Thread. 4.	Diameter at Bottom of Thread. B.S.P. Thread. 5.	Diameter at Bottom of Thread. Whitworth Thread. 6.	Number of Threads per Inch.
In.	In.	In.	In.	In.	In.	
$\frac{1}{8}$	$\frac{13}{32}$	0·383	0·3825	0·337	0·3367	28
$\frac{1}{4}$	$\frac{17}{32}$	0·518	0·518	0·451	0·4506	19
$\frac{3}{8}$	$\frac{11}{16}$	0·656	0·6563	0·589	0·5889	19
$\frac{1}{2}$	$\frac{27}{32}$	0·825	0·8257	0·734	0·7342	
$\frac{5}{8}$	$\frac{29}{32}$	0·902	0·9022	0·811	0·8107	14
$\frac{3}{4}$	$1\frac{1}{16}$	1·041	1·041	0·950	0·9495	
$\frac{7}{8}$	$1\frac{7}{32}$	1·189	1·189	1·098	1·0975	
1	$1\frac{11}{32}$	1·309	1·309	1·193	1·1925	
$1\frac{1}{4}$	$1\frac{11}{16}$	1·650	1·650	1·534	1·5335	
$1\frac{1}{2}$	$1\frac{29}{32}$	1·882	1·882	1·766	1·766	
$1\frac{3}{4}$	$2\frac{5}{32}$	2·116	2·047	2·000	1·9305	
2	$2\frac{3}{8}$	2·347	2·347	2·231	2·2305	
$2\frac{1}{4}$	$2\frac{5}{8}$	2·587	2·587	2·471	2·471	
$2\frac{1}{2}$	3	2·960	3·001	2·844	2·8848	
$2\frac{3}{4}$	$3\frac{1}{4}$	3·210	3·247	3·094	3·1305	
3	$3\frac{1}{2}$	3·460	3·485	3·344	3·3685	11
$3\frac{1}{4}$	$3\frac{3}{4}$	3·700	3·698	3·584	3·582	
$3\frac{1}{2}$	4	3·950	3·912	3·834	3·7955	
$3\frac{3}{4}$	$4\frac{1}{4}$	4·200	4·125	4·084	4·009	
4	$4\frac{1}{2}$	4·450	4·339	4·334	4·2225	
$4\frac{1}{2}$	5	4·950	...	4·834	...	
5	$5\frac{1}{2}$	5·450	...	5·334	...	
$5\frac{1}{2}$	6	5·950	...	5·834	...	
6	$6\frac{1}{2}$	6·450	...	6·334	...	

Whitworth threads, large or small, coarse or fine, which simplifies the formation of screwing tackle, and of threading tools, and establishes a constant proportion between the depth and the pitch of threads. The top and bottom of the threads of 55° of angle are rounded off with radii to a depth of one-sixth at top, and one-sixth at bottom, or one-third in all. This device was adopted in order to prevent injury, which the points of the threads in screws and nuts, and in taps and dies might sustain by accident. The formula for the Whitworth thread is:—

$$p = \text{pitch} = \frac{1}{\text{number of threads per inch}},$$
$$d' = \cdot 9605\,p,$$
$$d = \text{depth} = p \times \cdot 64033,$$
$$r = \text{radius} = p \times \cdot 1373.$$

The Sellers' Thread.—Sellers, 1864, proposed a modification of the Whitworth thread. The angle is 60° (Fig. 82), and the top and bottom are formed with a flat instead of a radius. The thread was recommended by Mr William Sellers in a paper read before the Franklin Institute on 31st April 1864. It was recommended by a committee of that body on 15th December, and endorsed by the Government in 1868. It is therefore indifferently known as the *Sellers'*, the *Franklin Institute*, and the *United States Standard* Thread. Recognising the fact that the angle of a screw thread must be to a certain extent a compromise, this system adopts the angle of 60°, partly because it "seems to fulfil the conditions of least frictional resistance with the greatest strength, but chiefly because it is an angle more readily obtainable than any other, and it is also in more general use." The latter remark applied to the sharp vee thread which was at that time the United States standard. Then the question of the top and bottom of the thread was settled on the grounds that though the sharp thread is the simplest form, it weakens the bolt, and is liable to injury, as are also the tools used in its formation, and these more than counterbalance the slight reduction in wearing surface produced by topping. But the rounded tops and bottoms of the Whitworth thread were deemed objectionable by reason of the practical difficulties which result from its adoption. The reasons are that a vee tool used in the lathe will not finish the points, which must be done by a second traverse. Neither will one angle gauge serve for all sizes of threads. For these reasons the flat at top and bottom was substituted for the radius. This thread with its proportions is seen in Fig. 82, and in the table below.

The formula is:—

$$p = \text{pitch} = \frac{1}{\text{number of threads per inch}},$$
$$d = \text{depth} = p \times \cdot 6495,$$
$$f = \text{flat} = \frac{p}{8},$$
$$d' = p \times \cdot 866.$$

United States Standard, or Sellers' Thread.

Diameter in In.	No. of Threads per Inch.	Diameter in In.	No. of Threads per Inch.	Diameter in In.	No. of Threads per Inch.
$\frac{1}{4}$	20	$1\frac{3}{8}$	6	$2\frac{3}{4}$	4
$\frac{5}{16}$	18	$1\frac{1}{2}$	6	$2\frac{7}{8}$	$3\frac{1}{2}$
$\frac{3}{8}$	16	$1\frac{5}{8}$	$5\frac{1}{2}$	3	$3\frac{1}{2}$
$\frac{7}{16}$	14	$1\frac{3}{4}$	5	$3\frac{1}{8}$	$3\frac{1}{2}$
$\frac{1}{2}$	13	$1\frac{7}{8}$	5	$3\frac{1}{4}$	$3\frac{1}{2}$
$\frac{9}{16}$	12	2	$4\frac{1}{2}$	$3\frac{3}{8}$	$3\frac{1}{4}$
$\frac{5}{8}$	11	$2\frac{1}{8}$	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$
$\frac{3}{4}$	10	$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{1}{4}$
$\frac{7}{8}$	9	$2\frac{3}{8}$	4	$3\frac{3}{4}$	3
1	8	$2\frac{1}{2}$	4	$3\frac{7}{8}$	3
$1\frac{1}{8}$	7	$2\frac{5}{8}$	4	4	3
$1\frac{1}{4}$	7				

The flat faces and roots of the Sellers' thread have been adopted in several Continental threads, presumably because they are more readily cut than the rounding roots and points.

Sharp V Thread (*see* p. 82).

Diameter in In.	No. of Threads per Inch.	Diameter in In.	No. of Threads per Inch.	Diameter in In.	No. of Threads per Inch.
$\frac{1}{4}$	20	$1\frac{1}{8}$	7	$2\frac{5}{8}$	4
$\frac{5}{16}$	18	$1\frac{1}{4}$	7	$2\frac{3}{4}$	4
$\frac{3}{8}$	16	$1\frac{3}{8}$	6	$2\frac{7}{8}$	4
$\frac{7}{16}$	14	$1\frac{1}{2}$	6	3	$3\frac{1}{2}$
$\frac{1}{2}$	12	$1\frac{5}{8}$	5	$3\frac{1}{8}$	$3\frac{1}{2}$
$\frac{9}{16}$	12	$1\frac{3}{4}$	5	$3\frac{1}{4}$	$3\frac{1}{2}$
$\frac{5}{8}$	11	$1\frac{7}{8}$	$4\frac{1}{2}$	$3\frac{3}{8}$	$3\frac{1}{4}$
$\frac{11}{16}$	11	2	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$
$\frac{3}{4}$	10	$2\frac{1}{8}$	$4\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{1}{4}$
$\frac{13}{16}$	10	$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{3}{4}$	3
$\frac{7}{8}$	9	$2\frac{3}{8}$	$4\frac{1}{2}$	$3\frac{7}{8}$	3
$\frac{15}{16}$	9	$2\frac{1}{2}$	4	4	3
1	8				

The Sharp V Thread.—This is still used in America (Fig. 82). It is supposed to be more readily cut than those forms which are truncated, but is not likely to survive permanently.

Its formula is :—

$$p = \text{pitch} = \frac{1}{\text{number of threads per inch}},$$

$$d = \text{depth} = p \times \cdot 8660.$$

(*See* table, p. 81.)

Metric Systems.—The Whitworth thread is worked by on the Continent, chiefly in Germany, but it is adapted to the millimetre standard. The result is a bastard table compounded of English and metric figures. The screw diameter is given as in English inches, and the number of threads is given per inch. But the screw diameter is also stated in millimetres, and the diameter at the root of the thread similarly.

A close adaptation of the Whitworth is made in the Italian artillery system, but modified wholly to a metric base. The outside diameters are in even millimetres, but the pitch, the diameter at the root of thread, and the depth of threads all work out fractionally.

The attempts made on the Continent to standardise screw threads date from 1873 and 1874, when a first effort was made to substitute a metric for the Whitworth threads. The result was not encouraging, but it led to the formation of the International Screw Thread Congress, which has met on several occasions. Much has been done, but chiefly as yet in reducing the number of authoritative threads in use. This becomes more absolutely essential as engineering practice assumes an increasingly international character, though the time seems far distant when some one standard will survive for general machine work. When that time arrives it will doubtless see a metric system supersede those based on the inch—a modified Whitworth perhaps.

The International Thread ("*Système Internationale*").—This was proposed and accepted by a congress held at Zurich in 1898. Its angle is 60° (Fig. 82). The equilateral triangle which it forms has its base p, equal to the pitch, and the top and bottom are truncated. The root is finished with a curve. The curve and flat give a clearance between nut and bolt. The screw diameter is measured on the outside of the truncated thread, and the values of the diameters expressed in millimetres give the numbers of the screws. The same design is used for the French standard, only the sizes in pitch do not correspond entirely throughout each series.

The formula is :—

$$p = \text{pitch},$$

$$d = \text{depth} = p \times \cdot 6495 \text{ to } \cdot 704,$$

$$f = \text{flat} = \frac{p}{8},$$

$$c = \frac{d'}{16} \text{ to } \frac{d'}{24},$$

$$c' = \frac{d'}{8}.$$

The clearance may therefore vary, without affecting the other relations.

TABLE OF INTERNATIONAL SCREW THREADS.

Diameter in mm.	Pitch in mm.	Diameter at Bottom of Thread in mm.	Diameter in mm.	Pitch in mm.	Diameter at Bottom of Thread in mm.
6	1	4·70	33	3·5	28·45
7	1	5·70	36	4	30·80
8	1·25	6·38	39	4	33·80
9	1·25	7·38	42	4·5	36·15
10	1·5	8·05	45	4·5	39·15
11	1·5	9·05	48	5	41·50
12	1·75	9·73	52	5	45·50
14	2	11·40	56	5·5	48·86
16	2	13·40	60	5·5	52·86
18	2·5	14·75	64	6	56·20
20	2·5	16·75	68	6	60·20
22	2·5	18·75	72	6·5	63·56
24	3	20·10	76	6·5	67·56
27	3	23·10	80	7	70·91
30	3·5	25·45			

The De Lisle, or Lowenherz Threads.—These have been evolved from systems presented to the Association of German Engineers in 1870 and 1877. They are codified as the De Lisle Nos. 3 and 4, and Loewe systems. The feature which they have in common is the section of the thread, Fig. 82, generally termed the Löwenherz on the Continent. The section is that of an isosceles triangle inscribed within a rectangle, having the height d' equal to the base p. The depth of thread d is truncated at top and bottom to one-eighth of the depth d'. This therefore resembles the Sellers excepting that the thread angle is 53° 8'.

Cycle Engineers' Institute Thread (C.E.I.).—This (Fig. 82) has 60° of angle, and is stouter

than other threads, one-sixth of the pitch being cut off at top and bottom. The formula is :—

$$d' = p \times 0{\cdot}866,$$
$$d = p \times 0{\cdot}5327,$$
$$r = \frac{p}{6}.$$

Cycle Engineers' Institute Standard Threads.

All sizes given below are right-hand threads, except where otherwise stated.

Diameter in Inches.		No. of Threads per Inch.	Diameter in Inches.		No. of Threads per Inch.
Decimals.	Fractions		Decimals.	Fractions	
·056	...	62	·266	...	26
·064	...	62	·281	...	26
·072	...	62	·3125	$\frac{5}{16}$	26
·080	...	62	·375	$\frac{3}{8}$	26
·092	...	56	*0·5625	$\frac{9}{16}$	20
·104	...	44	1·000	1	26
·125	$\frac{1}{8}$	40	†1·290	...	24
·154	...	40	1·370	...	24
·175	...	32	†1·4375	$1\frac{7}{16}$	24
·1875	$\frac{3}{16}$	32	1·5000	$1\frac{1}{2}$	24
·250	$\frac{1}{4}$	26			

* For right and left hand thread.
† For left-hand thread only.

The Thury System.—This (Fig. 82) is a thread used for watchmaking, and fine mechanical work. It dates from 1878, and was designed by M. Thury for the Society of Arts, of Geneva. Here, as in the Whitworth, the basis of the system represents the mean average of a large number of screws collected from numerous factories in different countries. The depth d of the thread equals $\frac{3}{5}p$, the angle is $47\frac{1}{2}°$, the radius r at the point is $\frac{1}{6}p$, and that r', at the root is $\frac{1}{5}p$. The millimetre is the basis of the system, and it was determined that this was the pitch adapted to a screw having a diameter of 6 millimetres.

There is a "large series" Thury system for general machine work. In this series the numbers run from 0 to 20. The millimetre pitch, with diameter of 6 millimetres, is the commencement, as in the small series, but thence the dimensions become coarser. The pitch p is directly related to the diameter of a thread by the formula $d = 6\,p^{\frac{6}{5}}$. As this would give an unlimited number of sizes, it was necessary in order to formulate a standard series to adopt the successive powers of 0·9 millimetre for the pitch. The index of the power is used as a designating number for the screws. Thus the pitch of No. 6 screw is obtained by raising 0·9 millimetre to the sixth power, the pitch being therefore 0·53 millimetre, and the diameter 2·8 millimetres. From the figures so obtained in decimals of a millimetre, a series is got in decimals of an inch.

The Committee of the British Association, 1882-1884, adopted the table with its decimal rendering for the B.A. thread, Fig. 82, subject only to making the radii at point and root alike, namely $\frac{2}{11}$ of the pitch. The table shows the two systems in combination. The decimal dimensions in millimetres or thousandths of an inch are given to the left, and the metric dimensions to the right.

British Association Standard Threads.

Number.	Nominal Dimensions in Thousandths of an Inch.		Threads per Inch.	Absolute Dimensions in Millimetres.	
	Diameter in Inches.	Pitch.		Diameter in Inches.	Pitch.
25	10	2·8	353	0·25	0·072
24	11	3·1	317	0·29	0·080
23	13	3·5	285	0·33	0·089
22	15	3·9	259	0·37	0·098
21	17	4·3	231	0·42	0·11
20	19	4·7	212	0·48	0·12
19	21	5·5	181	0·54	0·14
18	24	5·9	169	0·62	0·15
17	27	6·7	149	0·70	0·17
16	31	7·5	134	0·79	0·19
15	35	8·3	121	0·90	0·21
14	39	9·1	110	1·0	0·23
13	44	9·8	101	1·2	0·25
12	51	11·0	90·7	1·3	0·28
11	59	12·2	81·9	1·5	0·31
10	67	13·8	72·6	1·7	0·35
9	75	15·4	65·1	1·9	0·39
8	86	16·9	59·1	2·2	0·43
7	98	18·9	52·9	2·5	0·48
6	110	20·9	47·9	2·8	0·53
5	126	23·2	43·0	3·2	0·59
4	142	26·0	38·5	3·6	0·66
3	161	28·7	34·8	4·1	0·73
2	185	31·9	31·4	4·7	0·81
1	209	35·4	28·2	5·3	0·90
0	236	39·4	25·4	6·0	1·00

The Sauvage Thread.—This, which may be regarded as the French, and their Admiralty Standard has the same section as the Sellers.

It is worked out very simply, the diameters and pitches being all even. The pitch increases by one millimetre, and increases successively by half millimetres.

The Acme.—This (Fig. 82) is a thread which often fulfils the function of the square thread without its disadvantages. The angle is 29°, giving an inclination of $14\frac{1}{2}°$ to the sides, resembling therefore the standard worm thread. The formulæ are as follows :—

$$\text{Width of point of tool for screw or tap thread} = \frac{\cdot 3707}{\text{No. of threads per in.}} - \cdot 0052.$$

$$\text{Width of screw or nut thread} = \frac{\cdot 3707}{\text{No. of threads per in.}}.$$

Diameter of tap = diameter of screw + ·020.

Diameter of tap or screw at root = diameter of

$$\text{screw} - \left(\frac{1}{\text{No. of linear threads per in.}} + \cdot 020\right).$$

$$\text{Depth of thread} = \frac{1}{2 \times \text{No. of threads per in.}} + \cdot 010.$$

THE ACME STANDARD THREAD.

Number of Threads per Inch Linear.	Depth of Thread.	Width at Top of Thread.	Width at Bottom of Thread.	Space at Top of Thread.	Thickness at Root of Thread.
1	·5100	·3707	·3655	·6293	·6345
$1\frac{1}{3}$	·3850	·2780	·2728	·4720	·4772
2	·2600	·1853	·1801	·3147	·3199
3	·1767	·1235	·1183	·2098	·2150
4	·1350	·0927	·0875	·1573	·1625
5	·1100	·0741	·0689	·1259	·1311
6	·0933	·0618	·0566	·1049	·1101
7	·0814	·0529	·0478	·0899	·0951
8	·0725	·0463	·0411	·0787	·0839
9	·0655	·0413	·0361	·0699	·0751
10	·0600	·0371	·0319	·0629	·0681

In some cases there are advantages in the use of special threads, as for instance in gun work, and in Continental railway work, when the possibility of invasion has to be remembered. Most of the Continental railways have their own special threads which are not used outside of their own shops.

M. E. Sauvage has described ten different types of French railway threads in use. Angles of 53° 8′, 43° 36′, 36° 52′, and 60° are included, and rounding, and flat roots and points, with different proportions of truncation. De Lisle, and Reuleaux have worked diligently in the effort to standardise threads.

Broadly the geographical distribution of the principal screw threads is as follows :—The Whitworth in Britain, and Germany, the Sellers in the United States, the International and the Thury in Switzerland, the Thury or the British Association generally, and various metric threads in France.

The Metric System.—In 1896, in England, a Committee of the House of Commons recommended that in two years the metric system of weights and measures should be rendered compulsory in this country. Happily, drastic legislation has not followed. When the adoption of the system becomes clearly necessary in the interests of manufacturers they may be trusted to adopt it voluntarily. It is better that the change should be gradual, and that the present and the metric should for a while be kept in service. British manufacturers are unquestionably handicapped in foreign countries by the retention of the inch basis, and it is certain that its disappearance is only a question of time. This will involve the sacrifice of the Whitworth and the Sellers threads, and many others will have to go, because a system to be universal must involve the abandonment of many metric threads which have but limited spheres of adoption. The Thury and the B.A. screws, practically identical, may be considered as settled for fine screws, or those below $\frac{1}{4}$ in. The International thread might possibly form a basis for engineers' coarse threads. The Whitworth labours under the disadvantage, that when metricised the number of threads is still retained in inches, which cannot be permanently tolerated. Pipe threads are still in a condition of confusion, the so-called standards being numerous.

Screw Wrench.—A spanner in which the width between the jaws is rendered adjustable by means of a short screw. It is used on outdoor work more than in the shops, solely to avoid carrying several spanners of different sizes.

Scribing Block.—*See* **Surface Gauge.**

Scrive, or Scrieve Board.—The board used by shipbuilders, upon which all the frame sections of a vessel are scribed as a guide to the workmen in bending the frames. It is made of joist planks abutting by planed edges, and forming total over-all dimensions of about 6 ft.

to 8 ft. larger than the section at midships. They are kept in close contact on the floor by driving in wedges between the outer boards and a strip of angle iron screwed down to the floor. Sometimes each two adjacent planks are bolted together with bolts passing through their centres. The top of the board being planed smoothly is painted black to show the scrive lines well.

Scroll Chuck.—*See* **Lathe Chucks.**

Scroll Gears.—A design in which the velocity ratio is varied throughout a revolution, the gears being of scroll shape, Fig. 83. On the line of centres the amount of variation in speed is set out. Then a rectangle is constructed on the centre of one of the wheels, with the length of each side being equal to one-fourth of the length of total variation. From each angle a radius is struck giving a quadrant of the pitch line of

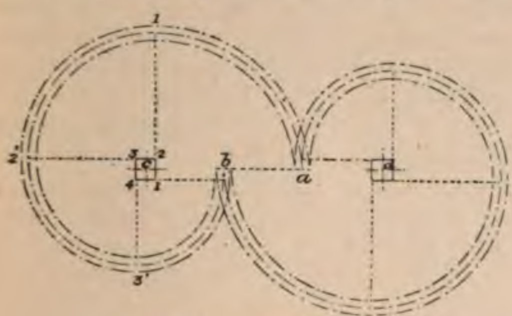


Fig. 83.—Scroll Gears.

the gears as shown, from 1, 2, 3, 4. From 1 as a centre with radius $1a$, the arc $a1'$ is struck; from 2 with radius 2 1′, the arc 1′2′ is struck and so on. Two scrolls with centres at *c*, *d* will engage correctly with a variation in speed determined by the locations of *a* and *b*. The teeth are struck suitably for the radius of each sector.

Scrubbing.—Hammering copper work all round in circles around rivets to depress the metal in the vicinity, so closing the joint and tending to draw the rivet out before closing.

Sculls, or **Skulls.**—The crust of metal left in a ladle after casting, and which adheres to the sides. It has to be broken out with a pinch bar, and the ladle re-daubed before another day's cast.

Scum Cock.—A cock bolted to the outside of a marine boiler for the purpose of getting rid of the dirt, grease, grit, and salt which are floated up to the surface of the water. It is connected by a pipe passing through the side of the boiler to a hollow *scum trough*, or a *perforated pipe* situated just below the water level. A pipe conducts the scum away from the cock to the side of the vessel. The scum cock may be used for reducing the level of the water in the boiler before adding *make-up* from the sea. Or the blow-off cock may be used for the purpose. The scum cocks must be opened frequently, both to prevent sticking of the plugs, and too heavy salting of the water.

A scum cock should have a clear area through equal to one-third of the blow-off cock. The clear area of the latter is equal to 1 sq. in. for each ton of water in the boiler.

The scum cock is usually of ordinary plug type design. A special design is made by Dewrance & Co. containing two plugs, one within the other, the object being to avoid the cutting action of gritty water which renders a cock leaky. In this design, one cock, the outer one, is opened and shut fully, the other, the inner one, regulates the discharge. The system of packing adopted is an indurated preparation of asbestos, in grooves surrounding the water ways. It cannot be injured by steam, or blown out.

Fig. 84 illustrates the Dewrance double plug scum cock in vertical section, external elevation, plan, and plan section. The following are the principal parts. A is the outer plug, B the inner. A is turned by the spanner C, B by the spanner D. But C and D have a certain connection through the horn E, by which at the first stage of opening they are moved in unison. Then the handles in the sectional view and in the plan below lie parallel with each other. In this position both plugs are closed, the pin F lying against the stop bar G on the body. When the cock is to be put into operation, the large handle C is turned from right to left through a quadrant of a circle. The outer plug A takes the inner plug B with it, pulling it by the horn E. This movement opens the outer plug A only. On turning the handle D alone through another quadrant, the inner plug B is set full open, and the blowing through takes place as long as the handles remain in those positions. The point is, that though blowing through is taking place, the surface

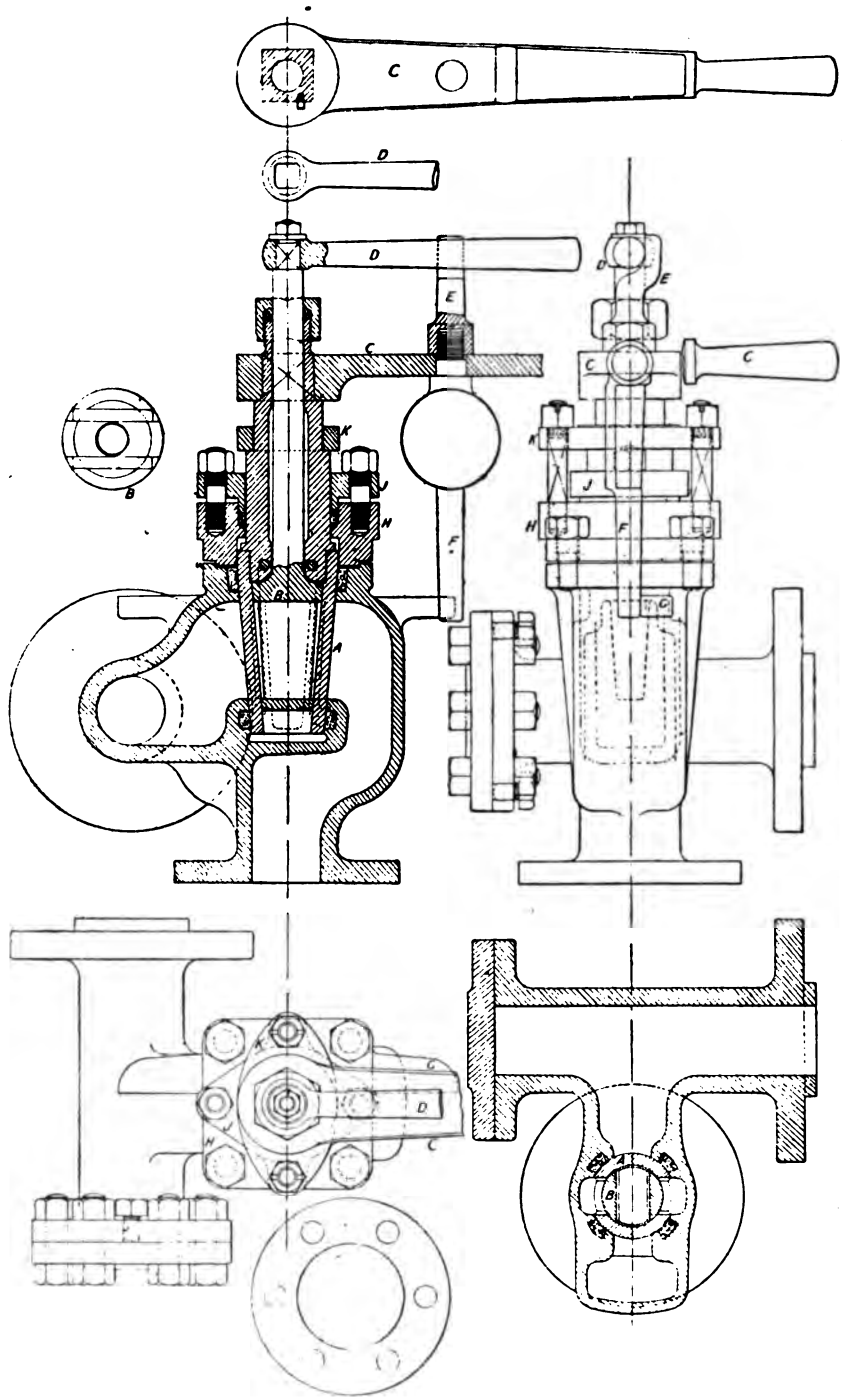


Fig. 84.—Dewrance Double Plug Scum Cock.

of the inner plug only is scored; the surface of the outer plug which is relied on to keep the cock tight, not suffering from the cutting action of gritty water. To shut off, both handles must be returned to the positions shown on the drawing.

These cocks are designed to withstand high pressures, and the arrangement of the cover and glands is termed by Messrs Dewrance the *counterbalanced construction*. It includes the flanged cover H, held down by bolts to the cock body, a stuffing box and gland J, and a holding-down plate K, which encircles the neck of the plug A, and forces the plug down with its cone.

The cock shown is built entirely of bronze, excepting the spanner C. The plug A is packed with indurated asbestos, which is caulked in grooves surrounding the water ways, and shown in the two sectional views. The connection of the plug A to its stem is by means of a screw, and hard bronze pins. Muntz metal is used for the stuffing box screws, and studs. These cocks are made in the 2-in. size only, which is sufficient for the largest boiler.

Sea Cocks.—Signifies in a general way the various cocks and valves which effect communication between marine engines and boilers, and the sea. They are attached to the skin of the hull. They consist of inlet, discharge, and bilge cocks, and are properly of non-return types, to prevent risk of accidental flooding. They are attached to a separate stand-pipe where desirable or necessary, and are of various kinds, according to their functions. The Board of Trade and Lloyd's insist on the observance of severe restrictions in their fitting. Fig. 85 shows a sea suction valve by Alley & Maclellan, Ltd., attached to its stand-pipe, bolted to the ship's side, and provided with a strainer. The valve is of the screw-down type.

Seam.—A lap joint united by riveting, welding, or soldering.

Seamless Tubes.—*See* **Tubes.**

Seam Set.—A tool used by coppersmiths for closing the seams made in work done in sheet metals.

Searing.—Smoothing the surfaces of wood patterns with a hot flat-iron in place of varnishing them. A polished browned surface is produced at less cost than by varnishing. Small holes which have to deliver themselves are seared with irons tapered to suit the taper of the holes. The practice is adopted for the cheaper classes of temporary patterns only.

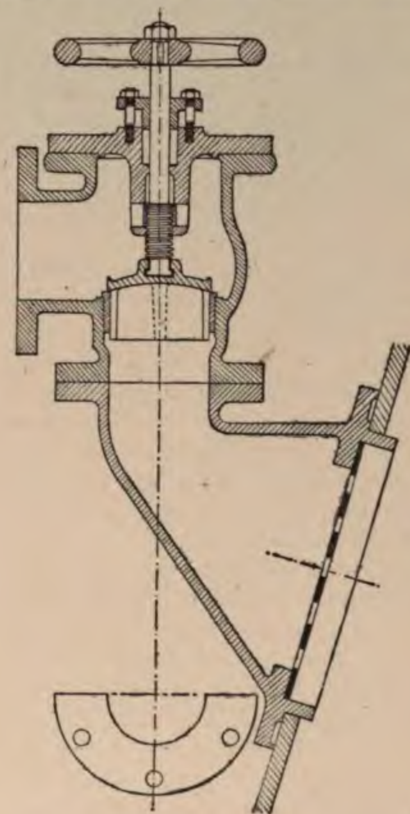


Fig. 85.—Sea Cock.

Seasoning.—Removing the sap from timber by allowing the atmosphere to play around it for a prolonged period. *See* **Timber Seasoning.**

Seat, or **Seating.**—Something which serves as a basis for the attachment of another object, as the seating of a safety-valve, or stop-valve, or cocks. Often synonymous with stand, or stool, or bed.

Section.—The cutting through of a mass in any direction. Or the aspect of the cut surface —applied particularly to drawings of objects. The aspects of portions that lie away from the outer faces can only be illustrated by sectional views. All interior parts, thicknesses of metal, and details are thus shown. The particular plane in which a section is taken is denoted by

prefixes, as *longitudinal*, *plan*, *transverse* or *cross*, *vertical*, or *oblique* sections respectively. If the view is confined to one particular plane, or if there is more than one section in the same direction, the planes are indicated by letters terminating the lines, as *section a-a*. Sections may be taken through irregular planes, but then this must be indicated by the course of the lines.

It is usual to place the aspect of the view in section in the same plane as that in which the severance is taken. It is not necessary, nor always convenient, but it facilitates rapid reading of the drawing.

It is customary to shade or colour distinctively the representation of a cut surface. Diagonal lines in close proximity, which vary with materials are used. Or distinctive colours on coloured drawings. *See* **Shading**.

Formerly all sectional shaded views were made distinct from the external views, though sectional unshaded views have always been indicated by dotted lines which distinguish edges that lie beyond external edges. Of late years the practice has extended of combining external and sectional views on one drawing, using full lines for both, and shading. The lines representing external parts are generally heavier than those which indicate the sectional aspects, and the shade lines of the latter are broken instead of full. An example occurs in Figs. 37 and 38, under **Screw-Cutting Lathe**.

Sectional Area.—The measurement of the area of a cross section. It relates specifically to the areas of solid and hollow shafts and columns, as bearing on their relative strengths to resist rupture by torsion, or by bending.

Sectional Boiler.—One which comprises an aggregation of independent units. Boilers of this type receive treatment under their specific names, and also generally under **Water-Tube Boilers.**

Sectional Paper, or **Squared Paper.**—Paper ruled with faint crossing lines, pitched at distances from about $\frac{1}{8}$ in. upwards. The squares so formed enable sketches to be done to a definite reduction or enlargement without measurement. The paper is made in sheets, in rolls, and bound up in the form of note-books. The larger units, as $\frac{1}{2}$ in. and 1 in., are generally marked by thicker lines, as a guide.

Sector.—A drawing instrument invented by Gunter, having the appearance of a carpenter's rule. The two legs are marked with scales which are laid down, not parallel to the edge, but converging, and these scales enable one to make various computations in a mechanical manner. A sector may contain any or all of the following scales:—a line of polygons, a line of chords, a line of sines, a line of secants, a line of tangents, a line of equal parts for operations involving the finding of a fourth proportional to three numbers, this latter being called the lines of lines. It will thus be seen that the applications of the sector are as varied as they are useful, but the following examples of its use must suffice.

Let it be required to find x in the proportion $3 : x :: 4 : 2\frac{1}{2}$. Open the legs of the sector until the distance between 4 on the line 0-L on one leg, and 4 on the same line on the other leg is exactly $2\frac{1}{2}$ in. Then the distance between 3 and 3 is the distance required in the proportion. Or let it be required to find a fourth proportional to $3\frac{1}{4}$, 5, $6\frac{1}{4}$. Open the legs till the distance between $3\frac{1}{4}$ on the two legs is equal to 0·5; then the distance from $6\frac{1}{4}$ to $6\frac{1}{4}$ is the fourth proportional.

A line may be rapidly bisected with the sector. Separate the legs till the distance between a pair of given numbers, say 6 and 6, is equal to the line requiring bisection. Then the distance between 3 and 3 will be half the given line.

To inscribe a regular polygon in a circle. As the side of a hexagon is the radius of the circle, the distance 0-6 (on the line of polygons) is the radius of the scale. Thus for any polygon the sector must be opened so that the distance 6-6 equals the radius of the circle; then the distance 7-7 gives the side of a heptagon, 8-8 that of an octagon, and so on.

A sector of a circle is the figure bounded by the two radii and the arc between them. For mensuration of sector *see* **Arc**, and **Areas**

Sector Gears.—Those in which velocity ratios are varied by dividing the peripheries into sectors, giving different velocity ratios. Thus in Fig. 86 there are three such ratios. The line of centres is divided out according to the ratios required, and the tooth shapes struck

to suit the different curves, just as though they were complete gears. The line of centres A-B, is divided at a' and f, and radii struck from the centres A-B. When the sectors a, b are engaged, wheel A is rotating more rapidly than wheel B. When arcs f, e are engaged, B is

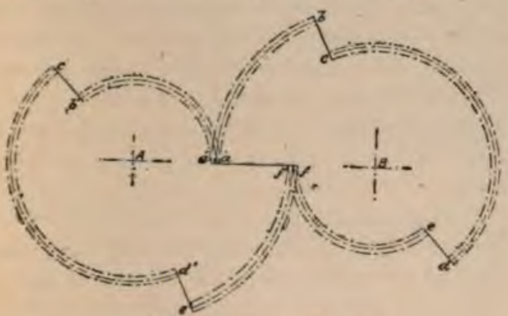


Fig. 86.—Sector Gears.

rotating more rapidly than A, but when c, d are engaged both wheels rotate at the same speed. Care must be taken that the teeth of one pair of sectors shall be disengaged before the successive pair are engaged, otherwise fracture would result.

Segment.—A segment of a **Circle** is the figure bounded by a chord and the arc it cuts off. For the mensuration of the segment *see* **Areas**.

Segmental Wheel.—Signifies an arc of a toothed wheel which imparts or receives a movement through an arc of a circle only. Also termed a *segmental rack*.

Segmental Work.—Building up in segments, instead of cutting from one solid piece of wood, is a very common practice in pattern-making, but is necessary to some extent in all curved woodwork. Its advantages are that short grain can be avoided, and warping and shrinking be prevented. A ring built of segments as in Fig. 87, A, is stronger and more permanent than a ring cut from a single piece of wood. A built-up ring is the commonest example of segmental work, but in pattern-making, segments are used in all constructions where there are curves and slender parts which would be short in grain, if cut from single pieces. Thus, a flange on a rounded corner may be built up as in Fig. 87, C, or a more complex edge may be made up as in D, either of one layer of segments, or more according to its depth. In B, a ring on a plate is shown with the plate built in segments, so that it presents end grain all round the circumference, and cannot shrink out of truth diametrically.

The usual number of segments in one layer of a complete circle or ring, as in A, and B, is six. Less than this brings in very short grain at their ends. In large rings more than six are employed. The layers in ordinary work are generally from about $\frac{1}{2}$ in. to 1 in. thick. As the strength of the work depends on their lapping joints, a ring as in A, no matter how shallow, could not be constructed with less than two layers, and three as shown, is more satisfactory. Segments attached to plates as in B, C, are often put on in a single thickness if the depth is not great. Segments are always glued together, and generally pegged, nailed, or screwed as well. Objections to the latter practice are that the insertion of nails or screws after gluing is likely to open the joint, and also as segmental work almost always has to be turned or otherwise finished to shape after the segments are together, there is some risk in slender work, of nails running sufficiently to one side to come in the way of the cutting tools.

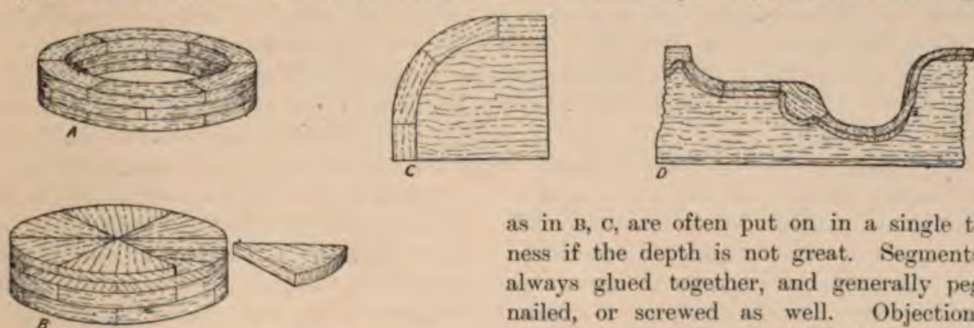


Fig. 87.—Segmental Work.

A section of the work to be built up is

marked out to full size, and divisions made to indicate the number of layers. Very often the work is of a shape which requires some of these to be wider than others, and they are cut and built in accordingly. One segment is marked out by striking the outer and inner radii, and drawing radial lines to its ends. When six segments to the circle are employed the radius gives the length of the segment. This segment is cut out and used as a pattern to mark the rest from. In work turned in the lathe the building up is done on the face plate, and each layer faced to a true surface, and to the thickness required before gluing on the next. The segments are fitted by planing their faces with a trying plane until each makes a close joint in the position in which it is intended to go. It is important that the end joints overlap as shown. The ends are generally fitted by cutting them with a trimmer. A more exact, though slower, way is to use a trying plane on its side with the segment laid on a shooting board. The segments are glued in place, one at a time, and generally cramped with hand-screws either until they have been nailed, or until the glue has set.

Seizing.—When metallic surfaces in frictional contact become so hot that the particles of metal become abraded, and torn out the term seizing is applied. As long as a film of lubricant is interposed, this mishap cannot occur, but only when metal runs in contact with metal. The remedy is to stop, and pour hot water on the journal, followed by cold water.

Self-Acting.—A machine tool is said to be self-acting in relation only to portions of its mechanism. Thus a slide rest is rendered self-acting by the lead screw, or the back shaft. The feed of a drill or cutter is self-acting when it is performed by gears or belts, as distinguished from that afforded by a hand lever, or a hand-wheel and screw. There may be more than one self-acting element in a machine. The distinction between a machine of this kind and one which is fully automatic is, that the movements of the latter are all performed automatically after the machine is started. A self-acting motion is an automatic one, but the machine as a whole is not automatic unless it fulfils the condition just stated. Self-acting movements are extremely common, but fully automatic machine types are relatively few in number.

Self-Centring.—The property possessed by various chucks used in lathes, drilling, and grinding machines, of concentric movement of the jaws; they operate simultaneously, so that an object is gripped and held in a central position without the necessity of making tentative trials and adjustments.

Self-Delivery.—The delivery of a pattern from the mould without requiring the use of cores.

Self-Excitation.—The characteristic of a dynamo which enables it to build up a magnetic field upon the rotation of its armature from the residual magnetism of its magnet poles.

Thus a shunt-wound dynamo will be self-exciting when started up with its armature circuit open, if the shunt be connected across the brushes, but a series-wound machine will excite only when on short circuit.

The connections of field windings are fully explained under **Dynamo**, &c.

Self-Fluxing Ores.—Iron ores which contain enough calcareous matter for fluxing without requiring any to be added to the charge.

Self-Induction.—When a coil or electro-magnet is excited by passing an electric current through its windings, and upon the breaking of the exciting circuit, a reverse E.M.F. or back-electromotive-force is produced tending to generate current which will flow in a direction opposite to that of the previous exciting current for a short period. *See* **Alternating Currents.**

Sellers Friction Discs.—An ingenious device first applied by Wm. Sellers to the operation of lathe feeds, Fig. 88. Though now nearly abandoned for that purpose, since cutting has become heavier, it is used in other ways, as for driving the feeds of cold iron saws.

The principle is that of wedge friction, applied to effecting a great reduction of speed, which permits of doing fairly heavy work. As originally applied to the feeds of screw cutting lathes, the discs were interposed between spur gears at the spindle end of the train, and others at the feed rod end. Solid discs, A and C, one at each end of the train, are gripped between

two adjustable discs B situated midway, the friction set up by the grip being sufficient to effect the driving. Equal grip is ensured for both, by pivoting the flanking discs B on globular seatings. The varying ratios of feed are obtained by the relative radial positions of the discs, the necessary movements being communicated to the flanking discs in a direc-

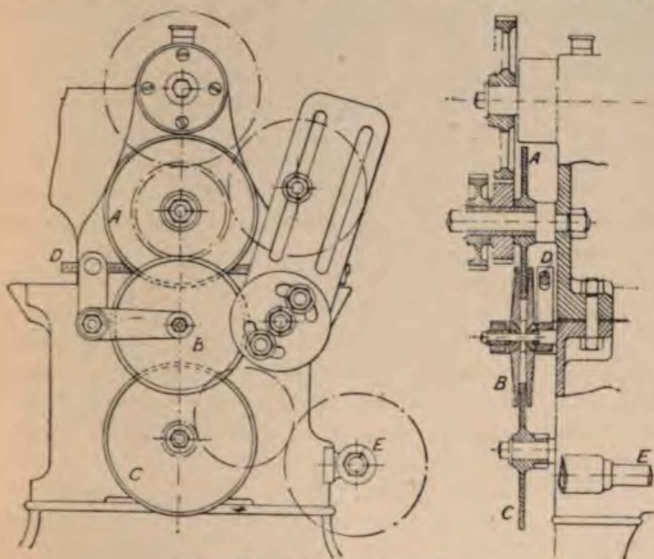


Fig. 88.—Sellers Friction Discs.

tion tangential to that of the solid ones, which movement is effected by a screw, D. The effect is to cause the grip to take place at varying distances from the centre of the movable discs B with corresponding differences of speeds of driving to the feed rod E. After adjustment, the flanking discs B are tightened on the others.

Semi-Automatic.—This is practically identical in meaning with the term self-acting. It signifies a machine, some of the movements only of which are automatic, and which therefore requires constant attendance. A common capstan lathe is the most familiar example of this type to which the term is applied.

Semi-Beam.—A beam supported at one end only. A cantilever.

Semi-Portable Engine.—*See* **Portable Engine.**

Semi-Steel.—A steely iron which may be produced in the puddling furnace. *See* **Puddled Steel.**

Sensitive Drilling Machine.—Small drills, below about half an inch in diameter, are so easily broken or twisted off by undue pressure that it is necessary to provide some method of feeding them in machines that will enable the attendant to feel the cut and pressure, and regulate the latter to a nicety. No form of screw feed will accomplish this, neither will it let the spindle be withdrawn quickly enough should occasion arise. A direct lever pressure is therefore employed, so that the drills can be worked up to the limit of their endurance, and yet be saved from breakage should uneven spots be encountered in the metal, or jamming occur through the cuttings clogging in the hole. The rapid movement of the spindle also permits the attendant to frequently raise the drill from its hole, for the purpose of clearing the chips.

There are two well-defined types of these machines, one in which the pressure lever is coupled to links attached to a loose collar at the top of the spindle, the other in which a loose sleeve encircles the spindle near the bottom, and has a rack upon it, moved up and down by a pinion and lever, so that as the sleeve goes up or down, the spindle, being coerced by collars, moves also. In all cases a spring, or a counterbalance tends to raise the spindle always to the topmost position.

The Slate type of sensitive drill is the best, including as it does the rack-fed sleeve and coiled counterbalance spring, and the drive through an endless belt, which laps around the pulley of one spindle, or around several in turn.

Fig. 89, Plate VI., shows a machine of this pattern by Messrs Alfred Herbert, Ltd., for holes up to $\frac{5}{8}$ in. The spindle runs in a top bush, around which the driving pulley is placed, and also in the feed sleeve, which is racked up and down to a limited extent in the adjustable bottom bearing; the latter can be slid up or down upon the face of the column, and clamped with the handle seen behind. A ring of balls receives the upward thrust of the

spindle against the face of the sleeve. The pulley at the base receives a belt from a three-stepped countershaft, and thence drives the drill spindle by another belt passing up over the idler pulleys. Slack is absorbed by moving the base pulley bearing downwards upon its circular stem, and clamping it again with the set-screw. The machine table is left plain, as shown, it being usually unnecessary to secure the work except by holding it with the hands. A stop collar is gripped to the spindle above the pulley, to enable holes of various depths to be drilled without gauging.

This machine is constructed for use on the bench; an independent pillar type is shown in Fig. 90, Plate VI. Here the upper work-table can be swung aside for deep work, leaving the lower adjustable table open to the spindle. When shafts, &c., have to be dealt with, a small cup centre, seen on the ground, is inserted in the socket of the lower table in place of the flat plate. The countershaft at the base renders the machine self contained. In another pattern there is only one table, and this slides upon the circular column, being balanced by a steel cord and counterweight inside the column. A clamping handle fixes the table firmly when in position. There is a hole in the centre to receive the loose cup.

Fig. 91, Plate VI., illustrates a heavier class of drill, for holes up to 1 in., and differing from the previous examples in having a star handle for feeding, and a slotted table, with rack and pinion motion for elevating. An electric motor at the foot drives through enclosed spur gears to the three-stepped cone, and the drill spindle has a two-stepped pulley, so giving six speed changes.

The multi-spindle machines are useful when several different sized holes have to be drilled in succession, or countersinking or recessing is required to be done. A good deal of time is saved, because it is unnecessary to change drills. Fig. 92, Plate VI., is a four-spindle drill of the same general construction as the previous machines, but having a common table for all the drill spindles, and a single belt arrangement for driving the four spindles. The cone about half-way up the column is driven from the counter at the base, and then an endless belt passes over the idlers, and round each spindle pulley. Two vertical idlers behind receive the belt as it passes from the outer spindle pulleys, the lay-out being somewhat similar to that shown in Vol. II., Fig. 122, N, except that the central back idler is omitted.

Separator.—A device for throwing down the particles of water which come off with steam in a condition of saturation, so leaving the steam free from condensed particles. *See* **Steam Separator.** *Also* **Centrifugal.**

Series Winding.—The method of winding an electro-magnet which provides that the whole of the current passing in the circuit of which the magnet is a function shall flow around the turns of the magnet coil. *See* **Dynamo, Electric Motor,** &c.

Series winding is not much used for dynamos (except in conjunction with shunt windings for compound-wound machines) but is often advantageous for motors for special purposes, such as electric cranes, electric pumps, electric traction, &c., or in other cases where it is convenient that the speed of the motor shall automatically vary with the load. Series winding is also frequently used in electrical mechanisms where an electrical balancing effect is desired, such as **Arc Lamps,** &c., where the power or position of the mechanism is to depend upon the current in the circuit. Also in electric meters a series winding is often arranged to influence or control the meter by its variable opposition to a shunt winding exerting an effect upon the controlling or operating device of the registering or revolving parts of the meter. *See* **Shunt Winding.**

Serve Tubes.—*See* **Tubes.**

Serving.—Winding a rope with spun yarn to prevent it from becoming chafed by contact with its pulley. A serving *board*, and a serving *mallet* are used for winding and pulling the yarn taut, and for compressing it. The board affords the necessary leverage.

Set.—Denotes the deflection of a bar or structure under stress. It is temporary, or permanent in character, safe, or dangerous in amount. It is safe while within the elastic limit, dangerous when it exceeds that.

Set Hammer.—A square-faced hammer, handled for use at the anvil. Its function is to


Fig. 89.—Bench Sensitive Drilling Machine.


Fig. 90.—Pillar Sensitive Drilling Machine.


Fig. 91.—Motor-Driven Sensitive Drilling Machine.


Fig. 92.—Four-Spindle Sensitive Drilling Machine.

(Alfred Herbert, Ltd.)

To face page 92.

set down shouldered parts on forgings. *See* **Smith's Tools.**

Set-off.—A common term which signifies generally the shouldering down of a portion of work, or the standing out of one portion from another, in line, or at an angle.

Set-over.—Relates to placing the centre of the mandrel of a lathe back poppet, or footstock out of alignment with that of the fast head, for doing taper work. *See* **Poppets.**

Set Screws.—*See* **Bolt.**

Set Square.—A square used for testing internal angles, and made of wood, metal, celluloid, or vulcanite. For convenience the angles which the hypotenuse makes with the base and perpendicular edges are either 45°, or 30° and 60°.

Setting Hammer.—A light cross-pane hammer alike at both ends, used for imparting the set to saws. *See* **Saw Sharpening.**

Setting of Boilers.—*See* **Lancashire Boiler.**

Setting of Valves.—*See* **Valve Setting.**

Setting-Out.—The same as lining out, or marking out work.

Setting Screws.—Set-screws used for the adjustment of take-up strips. They push the strips forward, and other screws at right angles effect the tightening.

Setts.—Chisels other than the common chipping chisel, used by fitters, smiths, and boilermakers. They are held in the hand, or by long handles, or reins, of iron or withy. They are of various shapes, with simple double bevelled chisel-like edges—the chisel setts, or curved—the gouge setts. They are used for cutting off cold metal—*cold setts*, or hot—*hot setts*, the latter being ground with a thinner bevel than the former.

Sewage.—With any sewerage system based on the water-carriage removal of sewage, particular local exigencies frequently require that some portion, if not the whole should be lifted. The installation of costly engines and pumping plant is being superseded by the use of automatic lifts and ejectors, working by compressed air.

In Shone's pneumatic ejector the sewage gravitates from the sewers into the ejector, an air-tight receiver, compressing the contained air. When the ejector is full of sewage, the compression of the air is such that a bell in the upper part of the chamber is lifted, and this, through the medium of an attached spindle, opens the compressed air admission valve. The valve on the inlet pipe is immediately closed, and the contents of the ejector are expelled through an outlet pipe into the sewage rising main or high-level gravitating sewer. A weighted cup at the bottom of the spindle then pulls down the bell and spindle, the supply of compressed air is cut off, the outlet valve falls on its seat, the air inside the ejector exhausts down to atmospheric pressure, and sewage again enters through the inlet valve.

The Adams' sewage lift is actuated by air compressed by a column of the sewage itself. In the highest part of the system is a "flush tank," fed with sewage or water. This is discharged through its pressure pipe to an "air cylinder" below, and the air displaced in this cylinder passes by an air pipe to a "forcing cylinder," the contents of which are thereby discharged through the rising main. The contents of the air cylinder are then withdrawn by a syphon, and the forcing cylinder is again filled with low level sewage. Where suitable gradients exist, the sewage lift chambers are placed below ground, and the sewage itself then operates the lift; otherwise the flush tank and air cylinder are placed as in a tower or column. This system is also very convenient for raising sewage in underground conveniences or the basements of hotels and institutions below the sewer level. In such cases, the water used for the flush tank is afterwards stored in a tank to supply lavatories.

The introduction of methods of sewage disposal by chemical or by bacterial treatment is of special interest to the engineer, owing to the demand for appliances for receiving and handling the sewage in its different stages of purification. As stated under **Bacteria Beds**, it is now conclusively proved that raw sewage may be completely purified by natural processes, and that given suitable conditions, the micro-organisms present in the sewage are capable of liquefying offensive solid matters and converting them into harmless nitrates and nitrites. Before arriving at this knowledge, much experimental

work was done in chemical precipitation, and many authorities have adopted this method of disposal. The precipitants that have been or are employed are lime, sulphate of alumina, protosulphate of iron, alum, ferrozone, and sulphate of iron.

Precipitation takes place in large shallow tanks having a depth of 4 ft. to 5 ft. at one end, and 6 ft. at the other, the lower surface being inclined towards the inlet end to allow the sludge to gravitate or be swept in this direction. The clear liquid in the upper portion of the tank slowly overflows in systems of "continuous" sedimentation, or is decanted after a period of rest, when a system of intermittent filling is adopted, and the sludge is withdrawn when a quantity has accumulated. In Candy's system the sludge is drawn from the bottom of the tank through a perforated pipe, and so discharged.

The liquid sludge is black and of a powerful odour. It contains as much as 90 per cent. of water, while the analysis of dry sludge reveals 56·53 parts of volatile and organic matter, 29·12 sand and insoluble matter, 14·35 other organic matter. In summer time it rapidly putrefies, and requires frequent removal from the tanks. The problem of the disposal of this offensive sludge has been variously solved: (*a*) by shipping it and depositing it in the deep sea; (*b*) by drying in trenches and digging it in; (*c*) by burning it when dried; (*d*) by converting it into cake for manurial use. Sludge is converted into cake in a filter press which consists of a number of square iron discs sliding on guides, and forming when pressed together a body resembling in shape a square prism. The face of each plate is recessed and grooved, and covered with a filtering cloth. The hollow spaces between the plates are filled with wet sludge, and pressure is applied at one end by a heavy press head. In small presses operated by hand power, the press head is moved backwards and forwards by means of a rack and pinion, pressure being applied by a wheel (or nut), with slots, turned with the aid of levers. In those of larger size, compressed air or hydraulic power is used to close the press. The liquid passes through the filtering material and trickles down the grooves of the plate through an outlet at the bottom to a trough. Sludge is forced into the press by means of a ram operated by compressed air. Screening apparatus is advisable to prevent the entrance of foreign material such as waste cloths, mop heads, &c., entering the pressing plant.

The resulting dry sludge cakes weigh about one-fifth of the original weight of the wet sludge, and contain only about 50 per cent. of moisture. There is some difference of opinion as to the manurial value of the cake. Much of course depends on the quality of the sewage. Though the original micro-organisms are present, the mass is practically sterile, until exposure to the weather and the warmth of the soil awaken bacterial life.

The expense of chemical precipitation, and the resulting problem of sludge disposal are avoided by the all-bacterial treatment of sewage. After treatment in septic tanks and filter beds, the foulest sewage issues as a clear and odourless effluent. Sewage as it leaves the sewers contains much insoluble and foreign matter which would clog automatic apparatus, and choke the contact beds. The sewage is therefore frequently led into a detritus chamber, in which such matter either sinks to the bottom or is intercepted by wrought-iron screens. John Smith & Co. make an automatic sewage screen in the form of an endless flexible screen band carried on a pair of drums. The apparatus is driven by the flow of the sewage itself by means of a water-wheel, so that the speed of the band is always adjusted to the rate of the flow of sewage. As the sewage passes through the band, sticks, hair, paper, rags, &c., are arrested and drawn up and deposited on the receiving platform, or into a worm conveyor. From the detritus chamber, screening chamber, catch pit, grit chamber or whatever it may be named, the sewage is carried to the septic, sedimentation, scum or liquefaction tank, and thence to the filter beds. The problem of conveying the liquid from chamber to tank, and tank to bed, and from bed to bed has resulted in the invention of many devices, most of which work of necessity automatically. Messrs Adams were the first to make such apparatus for operation. Mr Dibdin's original bacteria beds at Sutton, Surrey, laid down in 1895, are shown in the photograph, Fig. 93, Plate VII.

ssrs Mather & Platt's automatic measuring is designed to regulate the quantity of ge passing from the sedimentation tank to ontact bed. Pivoted about a horizontal are a flap valve, counterbalance weights, cylindrical balance drum. The drum is ected by a flexible pipe, with a measur- hamber fed from the sedimentation tank. n this measuring chamber, and consequently alance drum are empty, the latter is raised he counterbalance weights, and the flap closed. As the measuring chamber fills, ge flows through the flexible pipe into the , until its weight overcomes that of the erbalance weights; the flap valve is opened, measured quantity of sewage is discharged istribution over the beds. The contents e drum are discharged, and when the ber is empty the valve closes again.

e problem of periodical filling and empty- f bacteria beds has been specially studied dams Hydraulics, Ltd., who have devised al excellent automatic devices based on principle of the syphon. In filling a the air-lock feed cuts off the supply of ge by the action of the rising liquid in ressing and forcing the air in a dome igh a pipe to the interior of the feed. For utomatic emptying of beds the syphon is d in a flushing tank drawing its supply the bed through a stopcock. The syphon n overdraw pipe dipping into the contact and through this pipe the liquid from the is transferred to the flush tank, and dis- ged by the syphon.

e difficulty of distributing sewage evenly the filter beds is reflected in the large ber of patent spreaders on the market. d perforated pipes laid on the surface of the have proved unsuccessful, so that the rity of these spreaders are designed to l in some way. The effluent is led into a nn erected in the centre of the bed, and along two or four arms extending to the mference of the bed, and lying just above surface of the filtering material. These are supported by tie rods attached to the al column. The arms are either perforated , or troughs from which the effluent issues ts, and so during each revolution is rained over the entire surface of the bed. Many of them are actuated by the flow of sewage itself, the reaction of the liquid issuing in jets from the arms bringing about a movement of rotation. The earliest rotary distributors were the invention of Messrs Candy, Whittaker, and Caink, and one of the most successful at the present time is the Candy-Whittaker buoyant sprinkler. The weight of the apparatus is not carried on bearings, but by a float or buoy, in the form of a cylindrical tank floating in a small chamber in the centre of the bed. The rotating part of the sprinkler is attached to the buoy, which also rotates. Another feature peculiar to this appliance is the frictionless mercury-seal joint, the bearings being enclosed in a mercury bath, reducing the friction to a minimum. This of course does not freeze, keeps out all water and moisture, and prevents rusting of the parts. Loss of mercury, owing to excess of head is prevented by a loosely fitting split gun-metal check ring, situated at the extreme upper part of the inside portion of the mercury seal. Mather & Platt produce an automatic rotating spreader with two or four arms, consisting of open troughs, or perforated pipes, the range of bed covered being from 14 ft. to upwards of 200 ft. diameter. A large spreader of this type laid down at Chichester is capable of dealing with a million and a quarter gallons of sewage in twenty-four hours. It is electrically driven, and a motor is placed at the extremity of each of the two arms, the arms being supported on carriages running on a circular track outside the filter bed. Another important installation is that at Huddersfield, where there are thirteen electrically driven spreaders, each with four arms for beds 207 ft. in diameter.

Adams Hydraulics, Ltd., claim that their Cresset distributor is nearly frictionless, owing to the particular form of joint, between the fixed supply and the revolving tank. With a head of 11 in. and upwards of water above the spray holes they revolve against the strongest head wind, and under normal conditions revolve with a head of only 1 in. of water above the spray holes. The same firm have an electrically driven distributor in which the driving power (two electrically driven fans) is applied at the

points of greatest leverage, the extremity of the arms. A distinctly novel and ingenious device underlies yet another distributor made by this firm. The sewage rises in a column at the centre of the bed, and is discharged from two arms on opposite sides to paddles, which then revolve. Each paddle imparts motion to an attached rod stretching right across the bed, and at the end of each rod is a reel which also is set in revolution. A continuous belt (carried by supports on the outer circle of the filter) is looped round the reel, and so the rod revolves round the central pivot. The sewage is distributed by a perforated arm depending from the rod.

The Scott Moncrieff rotating distributor, by Manlove, Alliott, & Co., is another type of spreader revolving like the hand of a clock, being supported at the outer end by a rail running all round the bed. The tank effluent flows into a vertical stand pipe in the centre of the bed, and the rotating arm is composed of a large main trough fed from this central pipe. Along one side of the main trough is a series of small short troughs, fed from the main carrier through a port which admits sewage according to the distance from the centre. This ensures even distribution, for, as in all revolving spreaders, the portions of the pipe or trough

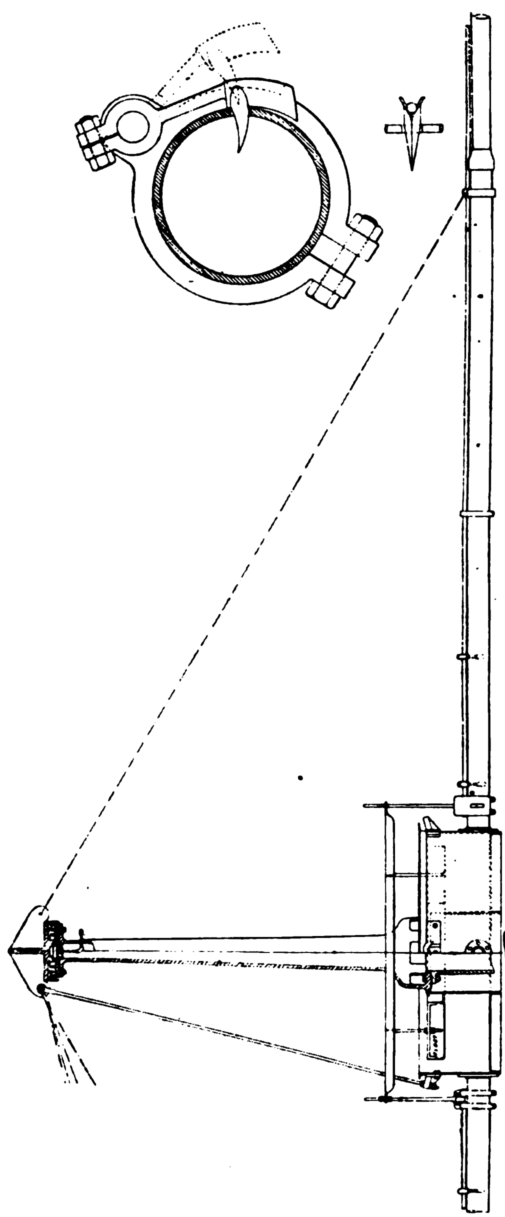
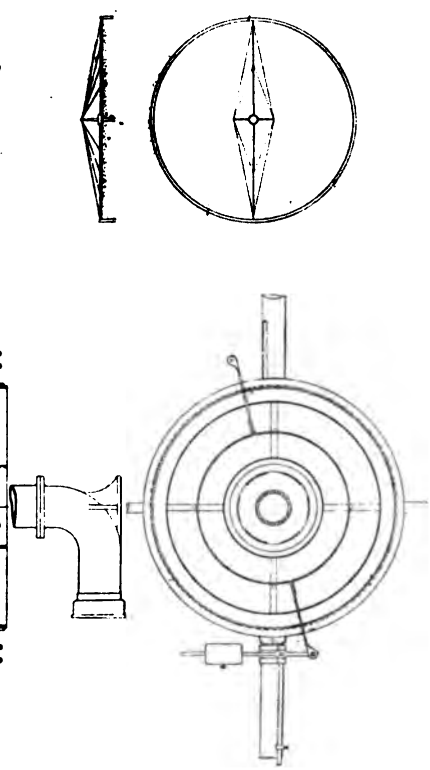



Fig. 94.—Rotary Sprinkler.

furthest from the centre, sweep over a greater area, in the same time, than those nearest the centre. The apparatus is driven by its own oil motor, and is independent of the head of sewage, or the velocity of discharge. A light gangway traverses the distributor, to allow of close observation of the bed, or inspection of working parts and effluent.

The majority of filter beds are circular in shape, but occasionally rectangular beds are constructed, and for these the Wilcox & Raikes Distributor is specially designed. This is an electrically propelled trough distributor which traverses the entire length of the bed on tram lines laid at the two sides. One side of the bed is fed, while the distributor travels in one direction, and the other half on the return journey.

Fig. 94 shows the construction of Messrs Burn Brothers' sprinkler; the centre piece is a tapered column, connected to the supply pipe by a duck-foot bend bolted to a concrete foundation. A head rotating on ball bearings at the top of the column takes the weight of the delivery tank, and of the arms by iron rods, and steel wire ropes. Each delivery arm (there are usually two) has a shaft lying parallel to it, supplied with a series of pivoted tapered fingers, having wings on the back, so as to divert the jets into two streams. Each shaft is connected to an annular float within the circular tank. Any increase or decrease therefore in the quantity of sewage imparts a corresponding movement to the float, so causing the holes in the arm to become increased or decreased in area. The action of the fingers renders the holes self-cleansing, since any choking would result in a rise in the tank, and a motion to the fingers which would clear out the orifices.

The tank effluent is sometimes distributed over the bed from fixed sprays, issued from pipes laid over the surface of the bed. This system has only its cheapness to commend it. A good head is constantly required, orifices become clogged up, and the distribution is uneven, a greater quantity of liquid being delivered at the outside edges of the area. Moreover, a number of sprays, circular in shape, are bound to leave unwetted a good proportion of any bed. To obviate the latter difficulty Adams Hydraulics, Ltd., have patented a square shaped spray.

Shackle.—A loop with a loosely fitting pin in the eyes, to which a chain hook, cable, or rope, is anchored. The pin is removable, being

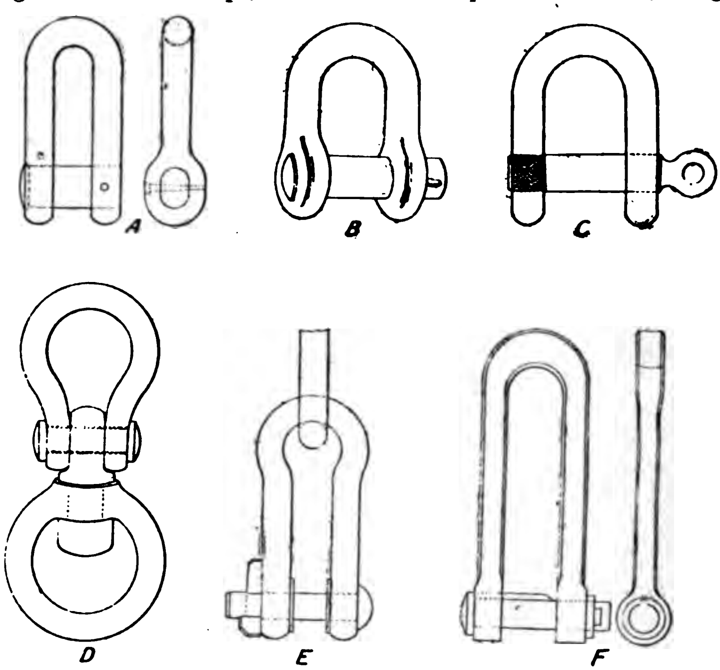


Fig. 95.—Shackles.

retained with a shoulder at one end, and with a pin or cotter at the other. A shackle may be pivoted to move in one plane only, or it may swivel to turn about in a complete circle. Shackles, like crane hooks are usually made of good wrought iron and bent to shape, rather than being stamped in steel.

Fig. 95 shows a few patterns of shackles. A is the ordinary type with the pin held in by a cross pin, while the pin of B is secured with a cotter. C is a screw shackle, and D a Jew's harp, or harp shackle riveted to the eye of a mooring ring, or swivel. A long type shackle

with cotter is seen in E, and at F a square link mooring shackle.

Shade Lines.—Thick lines placed on the lower and right-hand sides of objects drawn; the idea is that the light is assumed to shine from the left hand, at an angle of 45°, so throwing the work into shade at the portions named. The drawing not only has an improved appearance, due to the effect of relief, but the difference

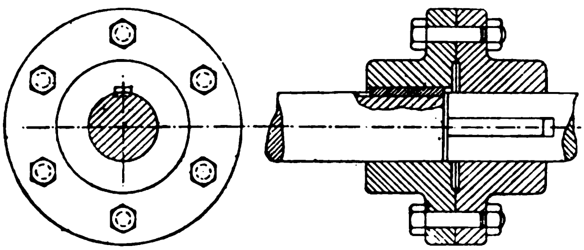


Fig. 96.—Flanged Coupling.

between recesses, and projections, or flush parts is at once apparent, by noting the thick lines. Very often the necessity for a second view of an object is obviated, the shade lines rendering the form clear. The drawings throughout this work have shade lines.

Shading.—Distinctive forms of lines are generally used on working drawings to indicate different materials, when colouring is not done, or when photo prints are required from the tracings. Plain lines denote cast iron, and in general any metal unless the following system is adopted. Steel is shown by dotted lines, wrought iron by alternate thick and thin lines, brass by alternate full and dotted lines, and lead by crossing lines. Stone is represented either by full lines, or by dotted, as for steel, and timber by an imitation of the grain. Many engineers do not trouble to make these distinctions, however, and all the metal on a drawing is shown by ordinary full lines, the respective names being written alongside, or shown on the detail views.

Shaft Couplings.—These should always be brought close to bearings, and on the side farthest away from the main drive. The shaft ends need not be enlarged to receive the couplings, as the case is not akin to that of screwed tie-rod ends. The shafts may be left parallel, or reduced at the ends to receive the couplings. A coupling should embrace its shafts securely, and run truly. It should be capable of ready fitting and detachment, to permit of sliding pulleys and wheels over the end of the shaft. It should have no projecting parts which might catch in clothes, and its price should be moderate. In the case of the smaller shafts, the question of the fitting, or absence of keys would have some weight. The coupling may or may not be made a means of assisting the bolts to maintain the concentric relations of the shafts.

The forms of couplings are more numerous than they were a few years since, when the flanged type predominated. These have been the cause of numerous accidents in consequence of the projecting bolt heads catching in the clothes of oilers, and therefore they are deservedly falling into disuse in favour of those recessed or shrouded to protect the bolt heads. Solid forged couplings are seldom employed in shops, being costly and generally inconvenient. The solid sleeve or muff coupling is not of much value, but the split muff is a

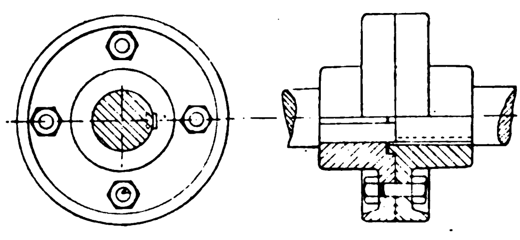


Fig. 97.—Recessed Coupling.

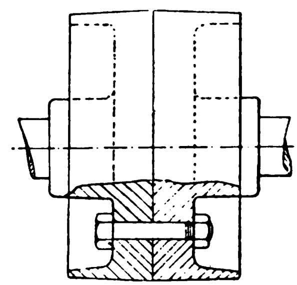


Fig. 98.—Coupling used as Pulley.

good type, as is also the cone design. We illustrate these types.

Flanged Couplings.—The dangerous form, which, nearly universal but a few years since, will in time be obsolete, is seen in Fig. 96. It

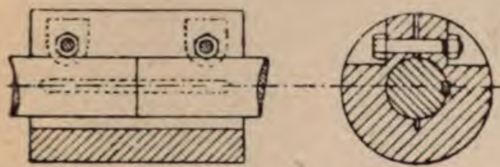


Fig. 99.—Solid Split Muff Coupling.

is bored to fit over the turned ends of the shafts, and is keyed on them. The faces generally abut merely, on an annulus, to lessen the area tooled. Sometimes they are checked into one another, but as often the shaft ends are made to meet within one half coupling as in Fig. 96,

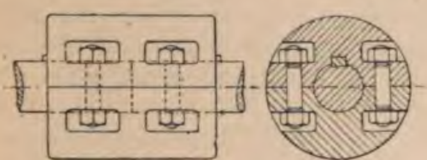


Fig. 100.—Muff Coupling.

which yields the same result. Besides the grave objection to the projecting bolts, there is also the fact that the method of fitting is of an inelastic character. The fit must be perfect for all couplings to interchange on all shafts. They must be just a push fit. Actually it is very difficult to ensure such accuracy, and if absent, then driving the keys throws the faces out of truth, and these when bolted up pull or strain the shafts out of line. So that it has been, and is still a common practice in shops where these are fitted, after the couplings have been keyed on, to put the shafts back in the lathe and skim the faces over slightly for the purpose of correcting them.

A much improved form of flanged coupling is the shrouded, in which the bolt heads and nuts are protected in annular recesses, Fig. 97. In other respects the remarks just made respecting common flanged couplings hold good. This design is also utilised sometimes as a small driving pulley, Fig. 98. In some designs recesses are arbored to receive the bolt heads and nuts. The objection to this is increased weight, and more expense in making.

Muff Couplings.—These are used in different forms. The solid split muff, Fig. 99, is not a good design, because though secure and safe, it is not so easily fitted and removed as other forms, Figs. 100, 101. In each case also keys are fitted, and these can be avoided by the adoption of improved methods of union, still retaining the muff as distinguished from the flanged design.

Cone Vice Couplings.—The advantages common to all these are the readiness with which they can be fixed and removed, their exact fitting in cases where there are slight differences in the diameters of shaft ends, and their absolute safety, while their cost is not greater than that of the flanged and muff types. The original of

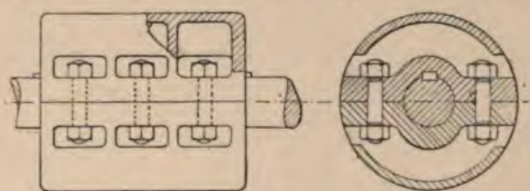


Fig. 101.—Muff Coupling.

these is the Sellers double cone vice coupling, introduced nearly forty years ago, and since modified in the hands of different makers.

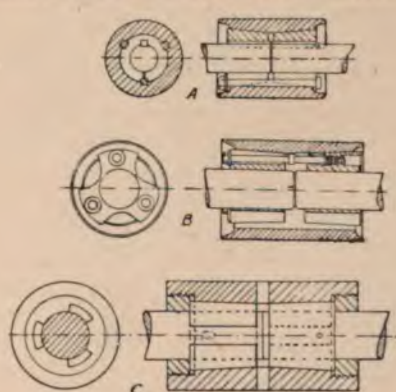


Fig. 102.—Cone Couplings.

The Sellers Coupling.—This, Fig. 102, A, consists of three main parts, an outer sleeve, two

inner cones, and the bolts. The interior of the outer sleeve is bored with a double taper, and

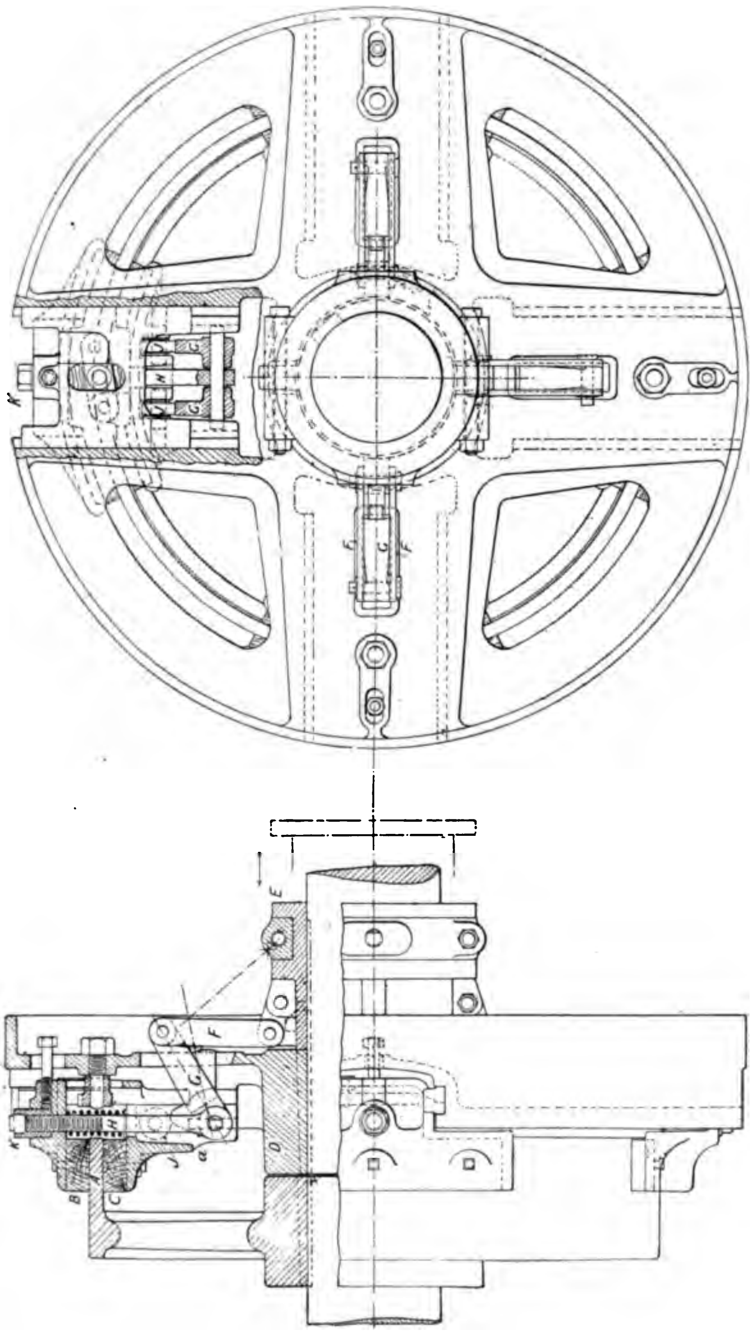


Fig. 103.—Rim Friction Clutch. (Croft & Perkins, Ltd.)

the exterior cones of the bushes which fit the shafts are turned tapered to correspond, and drawn up tightly with bolts which fit in grooves in the cones. A space is left between the small ends of the cones, so that they are not in contact when tightened round the shafts.

A variation on this is the substitution of a single taper, and a single inner cone in place of two. This is only suitable when shaft ends are of exactly the same diameter.

A modification of the Sellers' design, by the Unbreakable Pulley & Mill Gearing Co., Ltd., is shown in Fig. 102, B. In this the inner cones are split on one side, and made thin and flexible in two others, situated at 180° apart, and screwed up as shown. Keys are not required in shafts of less than 3 in. diameter.

Fig. 102, C, illustrates a modification of the cone design by the Kirkstall Forge Co. There are two cones, split on one side, with the splits set out of line with each other on the shafts, in order that one cone can be driven off with a drift passed through the split in the other. They are tightened and held with circular nuts screwed into the ends of the muff, and turned by tommy holes seen in the end view. Holes are provided round the centre of the muff through which the ends of the shafts can be observed.

Disconnecting Couplings.—These, also termed *clutches*, are used to throw lengths of main line shafts into and out of action instantly, or to drive sets of pulleys on shafts. The old claw couplings were the earliest forms used, but they are nearly superseded by improved types, with which it is not necessary to slow down, or else run risks of the claws becoming damaged when putting them into action. They may be thrown out at any speed.

The couplings which are taking the place of these are of some kind of friction design, many of which are in the market, some good, others unsatisfactory. Friction is set up between plain cylindrical bodies, or between cones. It is obtained either by toggle levers pressing split rings, or ring segments outwards against the bore of the outer fixed portion of the clutch, or by coil, or by spring friction, or by modifications of the same. Cone clutches are made in which metal or wood blocks form the frictional surfaces, and they may be of simple form with one pair only of surfaces in contact, or they may be conic-frustra in section, giving two pairs of surfaces in contact. Disc clutches are used, on the Weston principle, in which discs of iron or steel and wood alternate. Disc friction is utilised in other ways, with one or two faces only in contact.

Rim Friction Clutch.—One of this type by Croft & Perkins, Ltd., is seen in Fig. 103. The body carrying the rim A is keyed on the driving shaft. The slippers B, C, which grip the outer and inner surfaces of the rim, are carried in slides in the clutch body D. They are actuated by the sliding inwards of the sleeve E, which alters the positions of the toggles F, and levers G, as indicated by the dotted centre lines. The tension bolt H is pulled down, and with it the slipper blocks B against the outer edge of the rim, and the roller J is thrust upwards by the cam-like edge formed on the lever G, so pushing up the slipper block C against the inner edge of the rim A. The movement of the slider E is continued until the toggle F just passes the vertical, in which position the clutch is locked in gear without endlong pressure. Drawing the sliding collar E backwards releases the grip instantly, and the coiled spring round the tension bolt H lifts B off A, while the release of the roller J allows C to drop.

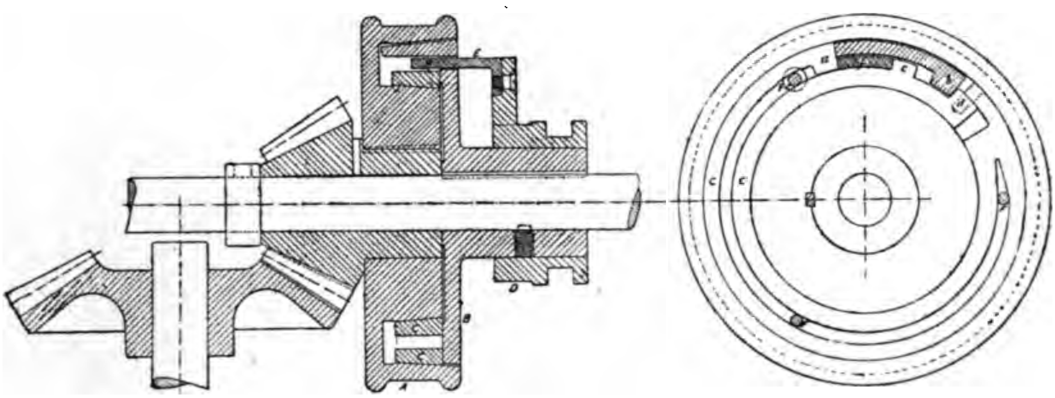


Fig. 104.—Toogood's Rim Friction Clutch.

Toogood's Double Coil Clutch.—This, which is made by Robert Dempster & Sons, Ltd., is illustrated by the drawings (Figs. 104, 105), and is of novel design. It is shown fitted to bevel gears, but it is equally suitable for belt pulleys, and it may drive a pulley, or its shaft be driven from a pulley.

In these figures, A is the casing to which a bevel wheel or a belt pulley is attached. It comprises an outer and an inner body, tapered. B is the sleeve which is keyed to the shaft, C is the double coil, D the slider to which a wedge piece E is screwed. (Compare with the separated details given in Fig. 105.) The sleeve B and double coil C are united, allowing freedom of movement of C by three screws F, one being

shown in section in the lower part of Fig. 105. The screws are adjustable to take up wear between the double coil C and its casing A.

Looking at the double coil C shown in face

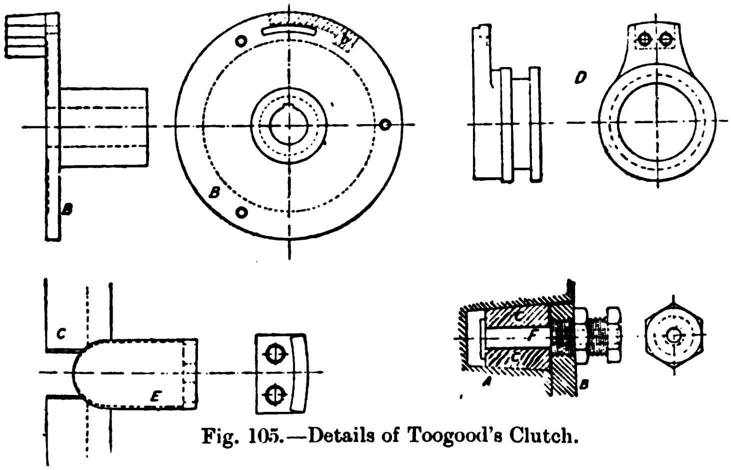


Fig. 105.—Details of Toogood's Clutch.

view to the right of the drawing, Fig. 104, certain projections will be noted, *a*, *b*, *c*, *d*. Of these *a*, *c* are on the coil, and *b* is on the sleeve B. Suppose the casing A is being rotated in the opposite direction to the motion of a clock, and the slide D being moved along carrying the wedge piece E with it, then the result will be that the outer portion of the coil C will be forced against the casing, and the frictional grip thus obtained thrust upon the junction of the two coil portions, with the result that the total final grip of the whole coil C will cause the lug *d* to press against the projecting lug on *b* of the sleeve B and carry the shaft round.

If the rotation were in the opposite direction, then the motion would be communicated from the lug *a* to the projection *b*.

There is a certain amount of freedom of movement between the lugs *c* and *b*, and *b* and *d*, and the adjacent shoulder of the double coil, and this slip lessens shock in starting.

The Champion Clutch.—This is a cone design manufactured by Messrs Durham, Churchill, & Co. In Fig. 106, A is a sleeve keyed to the shaft and having a flange *a* at one end. At the other end an annular groove *b* receives the striking ring B. On the ring a bracket receives the pin *c* which forms a fulcrum for the operating lever C. D is an anchoring arm the use of

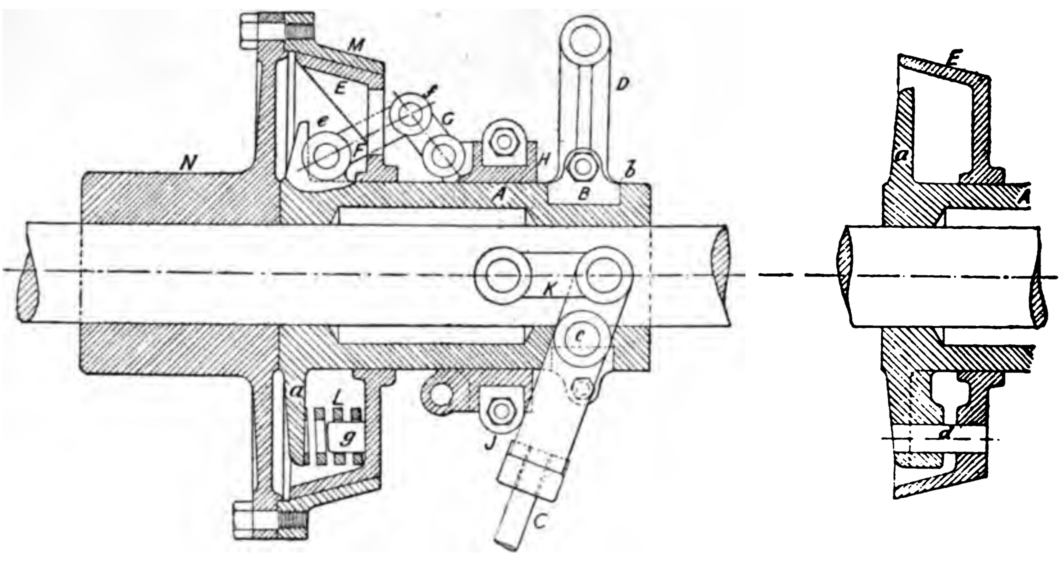


Fig. 106.—"Champion" Clutch.

which is to retain the lever in any desired position. On the flange *a* two bosses are cast on opposite sides of the diameter to carry driving pins *d*, which enter corresponding bosses on the inner cone E, and serve as carriers to E. There are two other bosses *e* on the flange *a* at right angles with *d*, to which are pivoted links F, which pass out through slots in the face of the cone E, and are pivoted to other links G by pins which carry rollers *f*. At the other end the links G are pivoted to the muff H, which is slid along by the operating lever C through the strap J and link K.

At certain positions on the inner face of the cone E, spring pegs *g* are fitted, encircled with springs L. These are under compression. When driving, their thrust forces the inner cone E along the sleeve A until the conical driving face of E is brought into contact with the corresponding face of the outer cone M, which cone is bolted to the flange of the boss N on which the pulley to be driven is mounted.

In the figure the clutch is shown driving in the manner already described. To throw it out of action, the lever C is moved to the right. The links K and straps J then push the muff H along the sleeve in the direction of the cones, so imparting to the links G a vertical position. The links F being pivoted thereto and to the flange *a*, the effect is to give a radial movement to the centres of the rollers *f*, which presses them against sliding faces provided for them on the faces of the cone E bounding the slot holes through which F F pass. The result is that the inner cone E is thrust away from contact with M, and the rotation of M ceases. As soon as the links G pass the vertical positions, the thrust of the springs L locks them, and the clutch remains out of gear. There is thus no endlong thrust in any portion of the operating gear. If the clutch is used for shaft coupling, the sleeve A is keyed to one shaft and N to the other.

Disc Clutch.—One by Messrs Croft & Perkins, Ltd., is illustrated, Fig. 107. It consists of two main portions, the friction disc A, which is made an integral part of the pulley boss, running loosely on the shaft, and the clutch body B, which is keyed to the shaft. The collar C being slid in the direction of the arrow operates the toggle D, and lever E, thrusting the movable pressure plate F against one face of the disc A, gripping

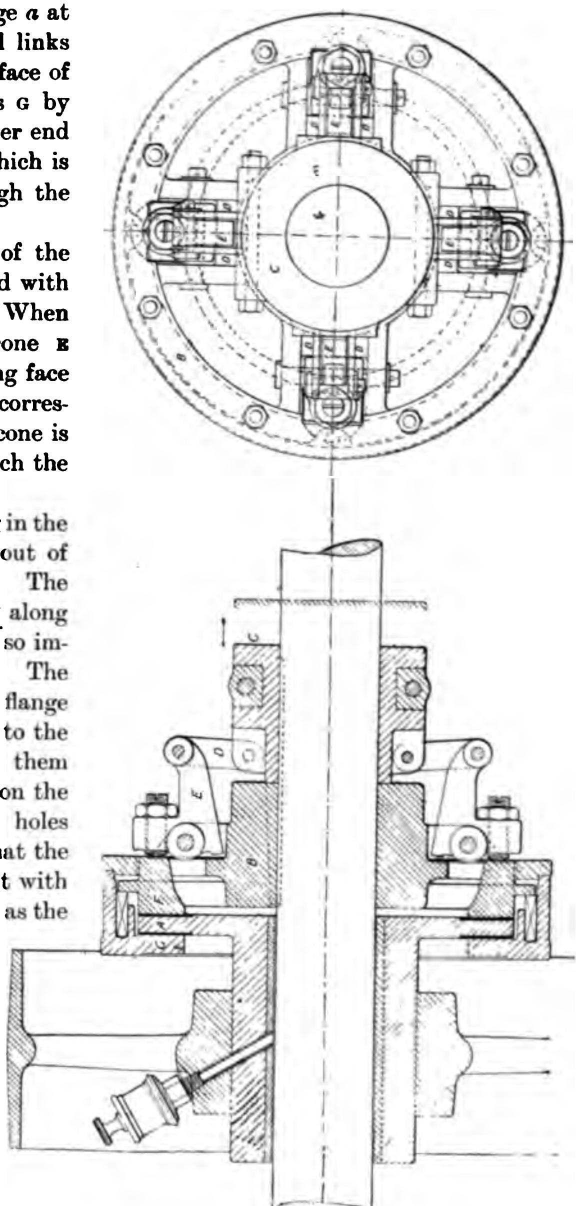


Fig. 107.—Disc Friction Clutch. (Croft & Perkins, Ltd.)

it thus against the fixed pressure plate G which is connected to the clutch body B. The pressure of the lever E is transmitted through the

screws, by which also adjustment is effected for wear. In the position shown with the toggle D just over the centre, the clutch is locked without end pressure existing. When the collar C is slid backwards the grip is instantly removed. The sliding collar may be double, and two clutches be operated alternately by one lever, Fig. 108, as in the case of reversing, or two-speed countershaft drives. The clutch may be adapted for exceptionally high speeds by a re-arrangement of the clutch levers, by which the action of centrifugal force is no longer opposed to the action of the clutch either when in or out of gear, Fig. 109.

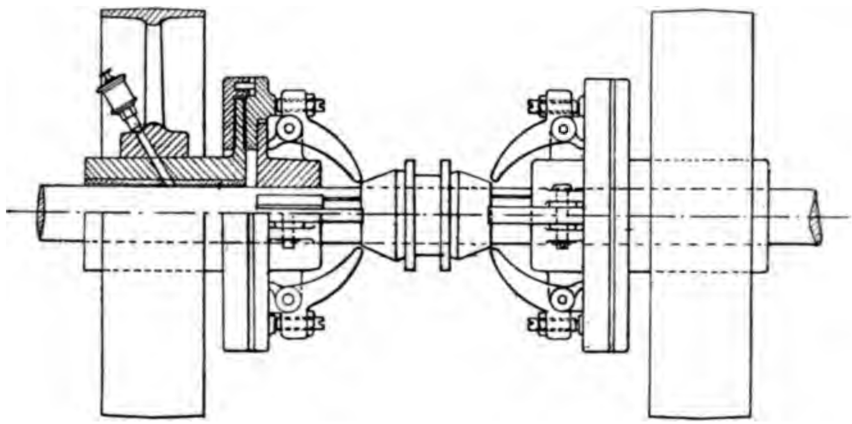


Fig. 108.—Disc Clutch adapted to Reversing Countershaft.

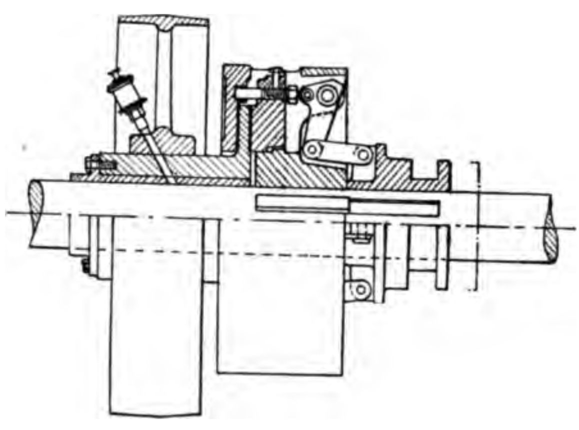


Fig. 109.—Disc Clutch adapted to High Speeds.

The Benn Friction Clutch.—This, Fig. 110, which has been patented and manufactured first on the Continent, is now made in England by the Unbreakable Pulley & Mill Gearing Co., Ltd. It is of the face design, and produces no end thrust on the shaft bearings or striking gear. The working parts are wholly enclosed in a box which is occupied by lubricant, and there is no centrifugal effort such as would be caused by variations in the radial positions of the revolving masses, the movements being endlong.

The clutch is illustrated by the drawings, while the successive action of the mechanism is shown by the diagrams, Figs. 111 to 113, in which the levers are exaggerated.

The clutch comprises a drum-like body, A, into the mouth of which a plate, B, is screwed with a square thread. A is keyed on its shaft, and is actuated from the driving boss C which is keyed on the other shaft. C is provided with arms, seen in Fig. 114, which carry the friction rings D, D round, through the medium of pins passing through the arms. The rings, however, are free to slide longitudinally on the pins parallel with the shaft. They are forced outwards by means of toggle levers E, E, which are actuated by the sliding of the striking collar F along the shaft, moving the levers G, G, and links H, H. Springs J, J are fitted at the long ends of the levers G, G to

afford the necessary pressure to the toggles and friction rings when the clutch is in gear.

lever, and the friction is equally divided between the surfaces in contact. Also, that as the

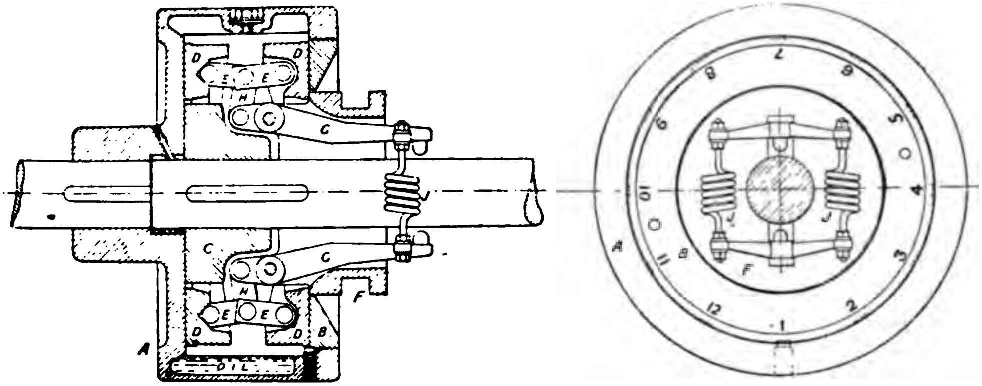


Fig. 110.—Benn Friction Clutch.

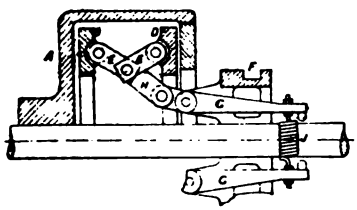


Fig. 111.

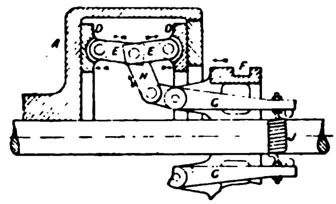


Fig. 112.

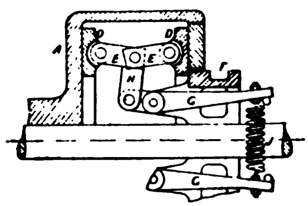


Fig. 113.

Benn Friction Clutch.

The action is shown exaggerated in the enlarged diagrams, Figs. 111 to 113. In Fig. 111 the clutch is out of gear. When the body F of the striking gear is slid along the shaft into the position shown in Fig. 112, the toggles E, E are forced into their most effective position, that is, nearly straight, and frictional contact takes place between the rings D, D and the interior faces of the drum, and the shaft is started. F may be advanced farther, with the result that the further movement of the springs H, H will cause a further extension of the springs J, J. When H, H pass the centres the stroke is completed and the springs, Fig. 113, lock the toggles in their in-gear position, and provide a constant force which maintains the frictional surfaces in contact so that the clutch is self-locking without end thrust. It is obvious, too, that equal force is exerted on each

position of the toggles is not affected by the tension of the springs, the tension of the latter

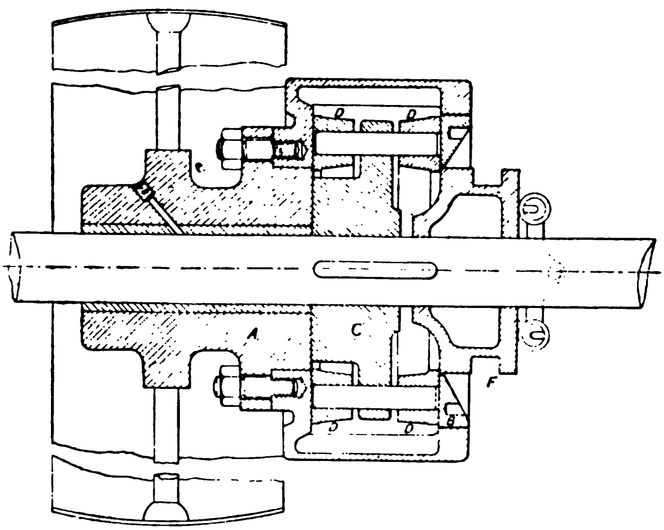


Fig. 114.—Benn Clutch applied to Pulley Drive.

can be adjusted to suit any load up to the capacity of the clutch. As a consequence

the clutch can be adjusted to slip at any overload.

The object of screwing in the covering plate B is to provide adjustment for wear. Gauge points on the springs J, J indicate by their position when the surfaces within the shell are wearing. When take-up is necessary, the plate B is screwed in, and numbered notches, Fig. 110, show when the clutch is restored to its original condition.

Lubrication is provided for by utilising the shell as an oil bath. When a clutch is running it does not require oil, because all parts are moving together. But when starting and stopping are being done, the oil descends and lubricates everything.

Fig. 114 shows the clutch applied to a shaft when the clutch has to drive, or be driven by a pulley. The latter is then provided with a flange which is bolted to the back of the shell of the clutch.

Shaft Governor.—An engine governor put on the crankshaft, to control the steam supply directly from the eccentric, by altering its throw, and angle of advance, and thence the cut-off of the valve. Its advantage over other governors lies in its perfection of speed regulation over wide variations in loads. Made in various designs, and to suit different kinds of engines the principle is alike in all, that of the action of centrifugal force acting on pivoted weights the outward movement of which is controlled by springs of definite tension. The general design is as follows:—

Two plates forming the body of the governor are connected at a definite distance apart by pins, and keyed on the crankshaft. There is thus no risk of lost motion due to the slip of a belt, or accident due to fracture of gears or a chain, but the governor partakes of the motion of the crankshaft. Two pivoted weights enclosed by the inner faces of the plates are free to move outwards or inwards respectively from their normal position, with diminution or increase of load respectively. The outward motion is resisted by the compression of spiral springs, the strength of which is obtained from a formula into which several factors enter.

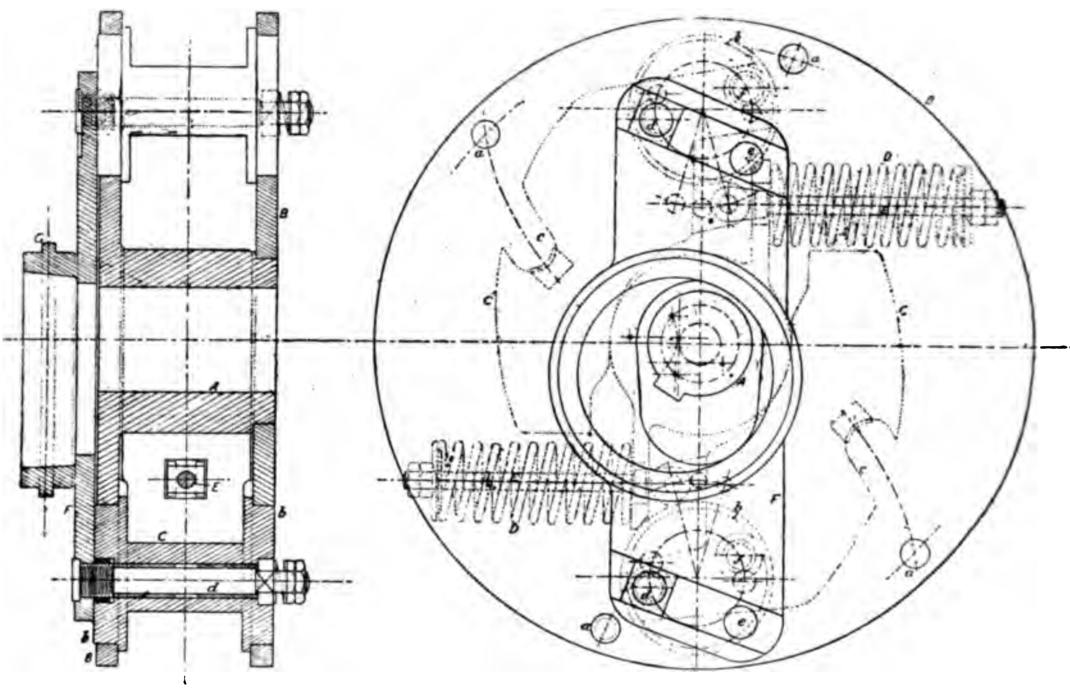


Fig. 115.—Turner-Hartnell Governor.

The weights are formed with turned bosses which pass through holes bored in the plates, in which they are free to turn. One of these bosses is connected to the eccentric directly through a plate, pins forming the connection. The effect is that when the weights are thrown outwards, the pins move the centre of the eccentric in a direction which reduces the throw and cuts off earlier. When they fall inwards, the opposite result follows. Nuts are provided for effecting slight adjustments in the tension of the springs. As a single eccentric only is used, reversal has to be effected by the insertion of pins in one or other of two sets of pinholes through the weight boss, and the adjacent eccentric plate.

The superior value of the shaft governor is undoubted. In the ordinary kind, which acts by throttling or wire drawing, the steam pressure is reduced so that the full advantage of expansion is] not obtained. In the shaft governor the steam is admitted at full pressure, and being shut off, works by expansion.

Some remarkable records might be given of the performances of the shaft governor. Mr Raworth once stated that he had put one on an 800 HP. engine, of which the high-pressure piston valve weighed between three and four cwt. and adjusted the springs until the speed was so uniform that no difference whatever could be detected between no load, and the full load of 500,000 watts, the engine making uniformly at these extremes 152 revolutions per minute. In the case of an engine for sawing, a shaft governor will maintain the same speed when cutting and not cutting. The reasons for the differences which exist between throttle and expansion governing generally are numerous, and were fully discussed in connection with a paper by Capt. Sankey, see *Proc. of Inst. of Mechanical Engineers*, April 1895.

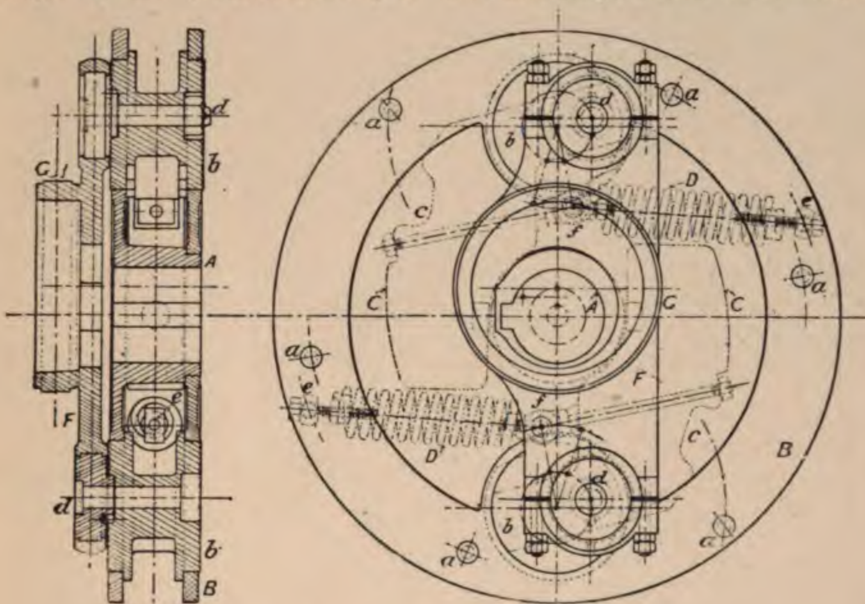


Fig. 116.—Turner-Hartnell Governor.

Figs. 115 to 117 illustrate the various Turner-Hartnell governors made by E. R. & F. Turner, Ltd., for small and large engines. Messrs Turner prefer governors with springs in tension rather than in compression, as they have found that springs in compression would buckle above a certain speed. But those in compression are the more sensitive. Both these designs are illustrated.

Fig. 115 is the disc pattern with springs in compression, for engines with speeds up to 200 revolutions per minute. The parts are as follows:—The hole in the central boss A is

bored to suit the engine crankshaft, and may be varied up to a maximum limit for a given size of disc. B, B are the discs encircling the boss, and secured with distance pins and ferrules *a*. Between these discs the weights C, C pivot on their bosses, which pass through the discs, and form integral parts of the weights. These are lubricated occasionally to ensure their absolute freedom of movement under the action of centrifugal force. The weights are notched at means of the pins *d*, which go through holes in the bosses. In moving through an arc, the minimum and maximum positions of which are indicated by dotted circles, they compel the eccentric G to alter its throw, and with it the travel of the slide-valve, and stage of cut-off of steam.

The pins *d* are shown located in one position, that for forward running. To change for backward, the pins are taken out of their holes, and

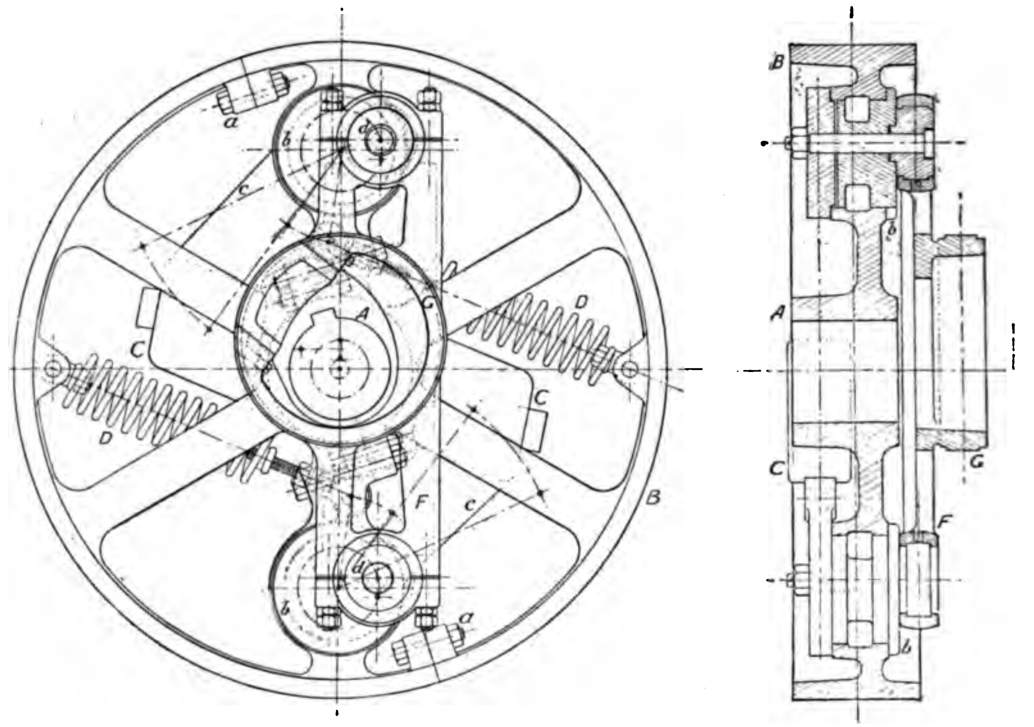


Fig. 117.—Turner-Hartnell Governor.

c, c, so that their free movement shall not be interfered with by the pins *a*. Indiarubber tubing is put over the stretcher bolts *a*, which acts as a buffer. In flying out, the weights compress, and are resisted by the springs D, through which the adjusting bolts E, E pass, being anchored in wings which form part of the central boss A.

As the weights change their radial positions the bosses *b* evidently partake of these movements, and turn in their holes in the discs. These turning movements are communicated to the plate F, on which the eccentric G is cast, by reinserted in the holes *e*, *e* in the plate F, and *f*, *f* in the bosses *b*. The oblong hole in the centre of the plate permits of the necessary movement.

This type of governor is made in dimensions which range from 1 ft. 1½ in. to 2 ft. 7 in. diameter for main slides, and up to 4 ft. diameter for expansion slides.

Another Turner-Hartnell disc pattern is shown in Fig. 116, for small engines with speeds of from 100 to 600 revolutions per minute. As illustrated, it is of the design used for main slides, non-reversible. It is made reversible for

expansion valves. As in the previous example A is the centre boss, bored to fit the crank-shaft, B, B are the discs, maintained apart by the pins *a*, C, C the weights pivoted on the bosses *b*, *b* and having recesses *c*, *c* to clear the pins *a*. As the design is non-reversible, the plate F, which carries the eccentric G, is fitted to the weight bosses *b*, *b* by a stud, fitted eccentrically, and this is held with a pin *d*. As therefore the weight bosses turn in their holes under the action of the weights, the stud and pin attachments move in an eccentric circle indicated by the dotted lines in the view to the right, and so alter the throw of the eccentric G. The springs are anchored at *e*, *e*, and an eye bolt passes through each weight to connect to the springs at *f*, *f*, so pulling them. The nuts at *e*, *e* permit of effecting a slight adjustment for tension. This pattern is made from 17 in. to 33 in. diameter for main slides, and modified for expansion slides.

Fig. 117 illustrates the *open* design used for large engines with high pressures, and speeds up to 200 revolutions per minute. The open pattern is essential because the diameters made range from 42 in. to 60 in. The springs D, D are in tension. The bodies B are cast in halves when necessary, and united with bolts through lugs *a*, *a*. For main valves they are not reversible. This is the design shown in the drawing. They are reversible for expansion valves.

Essentially the design of Fig. 117 resembles that last described, subject to the modifying presence of the arms. The eccentric plate F receives studs carried on the weight bosses *b*, *b*. The plate is lightened. The weights C, C are of different shape, being massed at the ends of short arms coming from the bosses. Buffers are fitted to the inner and outer faces of the weights. The spring attachments and other details are obvious from the illustrations.

The table appended gives a record of trials made by Messrs Turner, in which the performances of a shaft governor, and ball governor are compared under precisely similar conditions, using the same single slide-valve in each trial.

A shaft governor by Ransomes, Sims, & Jefferies, Ltd., is shown by Fig. 118. In this a circular casting A, comprising a main body, and cover plates, bolted together at *a a*, is keyed on

CYLINDER, 10 IN. BY 12 IN., PORTABLE TRIALS.

	A.	B.	C.	D.
	SHAFT GOVERNOR.		BALL GOVERNOR.	
	Heavy Load.	Medium Load.	Heavy Load.	Medium Load.
Date of trial	Mar. 5, '06	Mar. 9, '06	Mar. 22, '06	Mar. 23, '06
Duration of trial	6 hours	6 hours	6 hours	6 hours
Revolutions per minute	131	132	126	133
Boiler pressure	100	100	100	100
Water evaporated during trial	4,750 lb.	3,900 lb.	5,682 lb.	4,524 lb
Temperature of feed water	93° Fahr.	111° Fahr.	98° Fahr.	116° Fahr.
Coal consumed during trial	756 lb.	560 lb.	920 lb.	694 lb
Water evaporated per lb. of coal	6·28	6·96	6·17	6·51
Mean I.HP.	29·63	22·04	29·1	21·37
Steam per I.HP. hour lb.	26·4	29·4	32·53	35·32
Coal per I.HP. hour lb.	4·2	4·2	5·26	5·42
B.HP.	26·55	19·79	27·09	19·98
Steam per B.HP. per hour	29·8	32·8	34·95	37·72
Coal per B.HP. per hour	4·7	4·7	5·66	5·79

Diagrams taken every 1½ hours. Kind of coal used, Bolsover, Derbyshire.

the crankshaft. The weights B, B are pivoted at *b, b*. In their outward movements they compress the springs C, C, being anchored at *e, e* to the spring rods D, D which pass through the centre of the coils. The eye studs *e, e* are tapped into the weights as shown.

The plated centre of the casting is perforated with two oblong slot holes, *c, c*. Through these, pin bosses *d, d* on the weights B, B project and receive links E, E. These impart a partial movement of rotation to the disc F through the links E, E, with which disc the eccentric G is cast. The disc is confined within a pair of straps H, one of which is cast on the outer face of the main casting. The links therefore vary the throw of the eccentric, and period of cut-off.

Shafting — Shafts. — Spindles of large dimensions used for the driving of machines, in the form of main, or countershafts, and embodied in the machines themselves. The term *spindle* is usually applied to small shafts, the terms however being relative. In both alike the stresses are combined of twisting and bending, though in short lengths neither are very pronounced. In long shafts, heavily loaded, the bending is the more serious evil which has to be guarded against, since a shaft may be stiff enough to resist torsional stress yet suffer from bending stresses. The torsional stress is in proportion to the power transmitted. It lessens with increase of velocity. The bending stress increases with the weight of the shaft and pulleys, and the pull of the belts. Torsional stiffness is not the same as torsional strength. The latter is independent of length, the former is not. Hence on this account, and because of bending stresses, the question of distance between the supporting bearings enters into all estimations of the capacities of shafts to resist torsional vibration and bending. From the mass of formulæ given by different authorities the following are directly consonant with practice.

The strength of shafting to resist torsion varies as the cube of the diameter. So that a shaft 3 in. in diameter is more than three times as powerful as one of 2 in. diameter. But the torsional stiffness is proportionate to the square of the area.

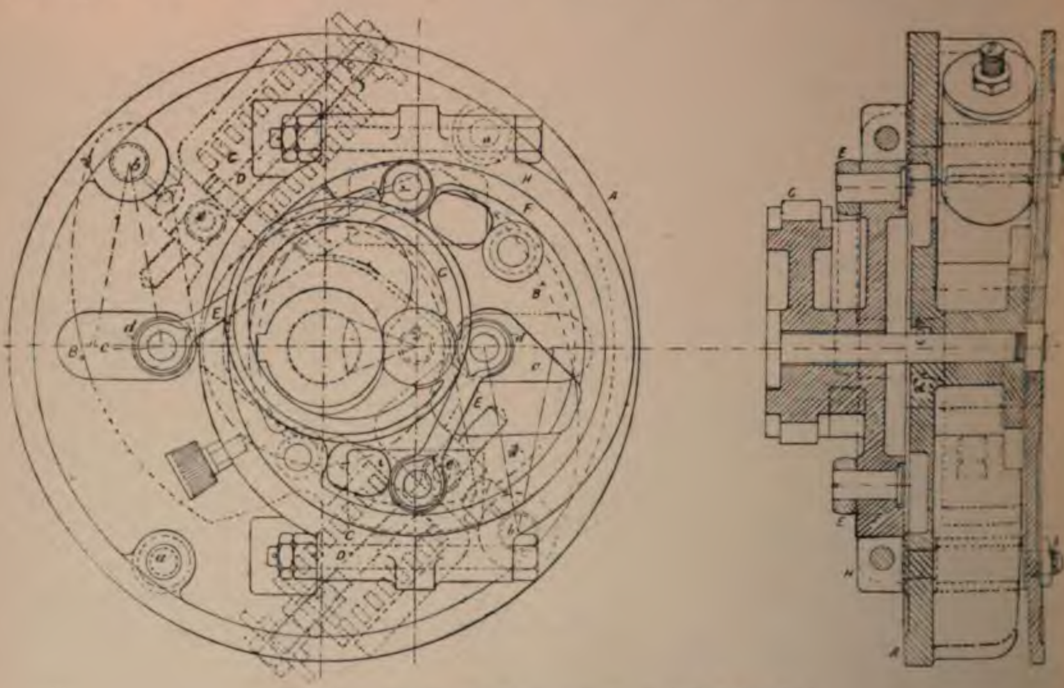


Fig. 118.—Governor by Ransomes, Sims, & Jefferies, Ltd.

The strength of shafts to resist torsion equals—

$$T = \frac{\pi}{16} fd^3 = 0{\cdot}196\, fd^3.$$

Where T = the twisting moment in inch pounds.
f = the stress per square inch to which the shaft is subjected.
d = diameter of shaft in inches.
$\pi = 3{\cdot}14159$.

The strength to resist bending equals—

$$M = \frac{\pi}{32} fd^3 = 0{\cdot}098\, fd^3.$$

Where M = bending moment in inch pounds.

The strength of a shaft subjected to a combined twisting and bending moment is equal to—

$$tm = M + \sqrt{(M^2 + T^2)}.$$

Where tm is the equivalent twisting moment which combines the twisting and bending moments T and M.

The horse power of shafts is equal to—

$$d = K\sqrt[3]{\frac{HP.}{N}}.$$

Where HP. = horse power transmitted.
N = number of revolutions per minute.
K = a constant, which varies with conditions.

The values of f and K, according to Professor Unwin, for ordinary shafts working with little change of stress, and without reversal, are. f =, for steel, 13,500, and for wrought iron, 9,000; K =, for steel, 2·876, for wrought iron, 3·292.

Engine shafting is stressed more severely than shop shafting, due to the variable character of the twisting moment, caused by variations in steam pressure, and of the crank leverage. The ratio of the maximum and minimum values of this moment determine the stresses. The ratio is greater with single cylinder engines with a large expansion, than in those with more cylinders and cranks. Mr Milton has given values for $\sqrt[3]{\frac{T \text{ maximum}}{T \text{ minimum}}}$ to be used as multipliers for the results obtained by the formulæ for twisting moment and horse power just given. For a single engine the multiplier given is 1·28. For a compound engine with cranks at right angles, it is 1·14.

Hollow shafts have been used in marine work since the introduction of fluid compressed steel. As there is no torsional stress at the centre of a shaft, the central portion can be removed, with much diminution of weight. A shaft is made much stronger for a given weight of material when it is disposed in the hollow than in the solid form. If d = the diameter of a solid shaft; d_1 = the external diameter, and d_2 the internal diameter of a hollow shaft, then it is demonstrable that the shafts will be of equal strength when

$$d^3 = \frac{d_1^4 - d_2^4}{d_1}.$$

Thus the moment of resistance of a solid shaft of diameter d_1 is—

$$\frac{\pi}{16} d_1^3 f.$$

If a central portion, = diameter d_2, is removed from the centre, the moment of resistance of the remaining part will be lessened by that of the portion of diameter d_2, reckoned as such before its removal, when it forms, not an independent shaft, but a portion of the interior.

If the stress at the outer diameter is f, then that at the inner is $f\frac{d_2}{d_1}$. Hence the moment of resistance of the inner diameter is $\frac{\pi}{16} d_2^3\, f\frac{d_2}{d_1}$, or—

$$\frac{3{\cdot}14159 d_2^4}{16 d_1} f.$$

Therefore the moment of resistance of the hollow shaft equals—

$$\frac{\pi}{16} d_1^3 f - \frac{\pi d_2^4}{16 d_1} f, \text{ equal to}$$
$$\frac{3{\cdot}14159}{16}\left(\frac{d_1^4 - d_2^4}{d_1}\right) f.$$

The relation between the weights of a hollow and a solid shaft is—

$$\frac{w}{w_1} = \frac{d_1^2 - d_2^2}{d_2}.$$

Where w = weight of hollow shaft.
w_1 = weight of solid shaft.
d_1 = outside diameter of hollow shaft.
d_2 = inner diameter of hollow shaft.

Line Shafting.—The calculations for this

TABLE OF HORSE POWER THAT GOOD STEEL SHAFTING WILL TRANSMIT.

Diameter of Shafts.	Revolutions per Minute.													
	10	20	30	40	50	60	70	80	90	100	110	120	130	140
1	·2	·4	·6	·8	1·0	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7
$1\frac{1}{8}$	·3	·5	·8	1·1	1·4	1·6	1·9	2·2	2·4	2·7	3·0	3·3	3·5	3·8
$1\frac{1}{4}$	·4	·7	1·1	1·5	1·9	2·2	2·6	3·0	3·4	3·7	4·1	4·5	4·9	5·2
$1\frac{3}{8}$	·5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0
$1\frac{1}{2}$	·6	1·3	1·9	2·6	3·2	3·9	4·5	5·2	5·8	6·5	7·1	7·7	8·4	9·0
$1\frac{5}{8}$	·8	1·6	2·5	3·3	4·1	4·9	5·7	6·6	7·4	8·2	9·0	9·8	10·7	11·5
$1\frac{3}{4}$	1·0	2·0	3·1	4·1	5·1	6·1	7·2	8·2	9·2	10·2	11·3	12·3	13·3	14·3
$1\frac{7}{8}$	1·3	2·5	3·8	5·0	6·3	7·6	8·8	10·1	11·3	12·6	13·9	15·1	16·4	17·6
2	1·5	3·1	4·6	6·1	7·6	9·2	10·7	12·2	13·8	15·3	16·8	18·3	19·9	21·4
$2\frac{1}{4}$	2·2	4·4	6·5	8·7	10·9	13·1	15·2	17·4	19·6	21·8	24·0	26·1	28·3	30·5
$2\frac{1}{2}$	3·0	6·0	9·0	11·9	14·9	17·9	20·9	23·9	26·9	29·9	32·9	35·8	38·8	41·8
$2\frac{3}{4}$	4·0	7·9	11·9	15·9	19·9	23·9	27·8	31·8	35·8	39·8	43·7	47·7	51·7	55·7
3	5·2	10·3	15·5	20·6	25·8	31·0	36·1	41·3	46·4	51·6	56·8	61·9	67·1	72·3
$3\frac{1}{4}$	6·6	13·1	19·7	26·2	32·8	39·4	45·9	52·5	59·1	65·6	72·2	78·7	85·3	91·9
$3\frac{1}{2}$	8·2	16·4	24·6	32·8	41·0	49·2	57·4	65·6	73·8	81·9	90·2	98·3	107	115
$3\frac{3}{4}$	10·1	20·2	30·2	40·3	50·4	60·5	70·6	80·7	90·7	101	111	121	131	141
4	12·2	25·4	36·7	48·9	61·2	73·4	85·6	97·9	110	122	135	147	159	171

Diameter of Shafts.	Revolutions per Minute.													
	150	160	170	180	190	200	225	250	275	300	350	400	450	500
1	2·9	3·1	3·2	3·4	3·6	3·8	4·3	4·8	5·3	5·7	6·7	7·6	8·6	9·6
$1\frac{1}{8}$	4·1	4·4	4·6	4·9	5·2	5·4	6·1	6·8	7·5	8·2	9·5	10·9	12·2	13·6
$1\frac{1}{4}$	5·6	6·0	6·3	6·7	7·1	7·5	8·4	9·3	10·3	11·2	13·1	14·9	16·8	18·7
$1\frac{3}{8}$	7·5	7·9	8·4	8·9	9·4	9·9	11·2	12·4	13·7	14·9	17·4	19·9	22·4	24·8
$1\frac{1}{2}$	9·7	10·3	11·0	11·6	12·3	12·9	14·5	16·1	17·7	19·4	22·6	25·8	29·0	32·3
$1\frac{5}{8}$	12·3	13·1	13·9	14·8	15·6	16·4	18·5	20·5	22·6	24·6	28·7	32·8	36·9	41·0
$1\frac{3}{4}$	15·4	16·4	17·4	18·4	19·5	20·5	23·0	25·6	28·2	30·7	35·9	41·0	46·1	51·2
$1\frac{7}{8}$	18·9	20·2	21·4	22·7	23·9	25·2	28·3	31·5	34·7	37·8	44·1	50·4	56·7	63·0
2	22·9	24·5	26·0	27·5	29·1	30·6	34·4	38·2	42·0	45·9	53·5	61·2	68·8	76·5
$2\frac{1}{4}$	32·7	34·8	37·0	39·2	41·4	43·5	49·0	54·4	59·9	65·3	76·2	87·1	98·0	109
$2\frac{1}{2}$	44·8	47·8	50·8	53·8	56·7	59·7	67·2	74·6	82·1	89·6	105	119	134	149
$2\frac{3}{4}$	59·6	63·6	67·6	71·5	75·5	79·5	89·4	99·4	109	119	139	159	179	199
3	77·4	82·6	87·7	92·9	98·1	103	116	129	142	155	181	206	232	258
$3\frac{1}{4}$	98·4	105	112	118	125	131	148	164	180	197	230	262	295	328
$3\frac{1}{2}$	123	131	139	148	156	164	184	205	225	246	287	328	369	410
$3\frac{3}{4}$	151	161	171	181	192	202	227	252	277	302	353	403	454	504
4	183	196	208	220	232	245	275	306	336	367	428	489	551	612

cannot be put into a simple and uniform formula, applicable to all line shafts. The question is not merely one of power transmission, but is affected vitally by those of stiffness, unit load on bearings, the distance apart of the bearings, the number and position of pulleys or gear wheels. It is therefore usual in text-books to give tables suitable for various conditions. Or, which is preferable, a table for average or ordinary power transmission is given, and the dimensions are to be increased according to the various circumstances which are found to exist. An extensive experience is embodied in the formula deduced by the Unbreakable Pulley & Mill Gearing Co., Ltd., from their own practice. It is:—

$$\left.\begin{array}{l}\text{Diameter of steel shaft}\\ \text{in inches required}\\ \text{to transmit a given}\\ \text{horse power, allow-}\\ \text{ing for the bending}\\ \text{strain of pulleys}\\ \text{and belts}\end{array}\right\} 3{\cdot}74\sqrt[3]{\frac{\text{HP. to be transmitted}}{\text{Number of revolutions per minute}}}$$

Diameters obtained from this formula are not to be used for main drives, in which case 50 per cent. should be added. In cases where bearings are farther apart than are given by the formula

$5\sqrt[3]{\text{diameter of shaft in inches}^2}$ = distance apart in feet, the diameter of shaft should be increased.

The tables annexed are calculated from the formulæ given, and are by the Unbreakable Pulley & Mill Gearing Co., Ltd.

TABLE OF DISTANCES OF BEARINGS APART, CENTRE TO CENTRE.

Diameter of Shaft.	Distance of Bearings.	Diameter of Shaft.	Distance of Bearings.	Diameter of Shaft.	Distance of Bearings.
In.	Ft. In.	In.	Ft. In.	In.	Ft. In.
1	5 0	$3\frac{1}{4}$	11 0	6	16 6
$1\frac{1}{4}$	5 9	$3\frac{1}{2}$	11 6	$6\frac{1}{2}$	17 6
$1\frac{1}{2}$	6 6	$3\frac{3}{4}$	12 0	7	18 3
$1\frac{3}{4}$	7 3	4	12 6	$7\frac{1}{2}$	19 0
2	8 0	$4\frac{1}{4}$	13 0	8	20 0
$2\frac{1}{4}$	8 6	$4\frac{1}{2}$	13 6	$8\frac{1}{2}$	20 9
$2\frac{1}{2}$	9 3	$4\frac{3}{4}$	14 0	9	21 6
$2\frac{3}{4}$	9 9	5	14 6	10	23 3
3	10 3	$5\frac{1}{2}$	15 6	11	24 9
				12	26 3

TABLE OF WEIGHTS OF TURNED STEEL SHAFTING.

Diameter of Shaft.	Weight per Foot of Shaft.	Diameter of Shaft.	Weight per Foot of Shaft.	Diameter of Shaft.	Weight per Foot of Shaft.
In.	Lb.	In.	Lb.	In.	Lb.
1	2·66	$3\frac{3}{4}$	37·4	8	170
$1\frac{1}{4}$	4·16	4	42·6	$8\frac{1}{2}$	192
$1\frac{1}{2}$	5·99	$4\frac{1}{4}$	48·1	9	216
$1\frac{3}{4}$	8·15	$4\frac{1}{2}$	53·9	$9\frac{1}{2}$	240
2	10·6	$4\frac{3}{4}$	60·1	10	266
$2\frac{1}{4}$	13·5	5	66·6	$10\frac{1}{2}$	293
$2\frac{1}{2}$	16·6	$5\frac{1}{2}$	80·5	11	322
$2\frac{3}{4}$	20·1	6	95·8	$11\frac{1}{2}$	352
3	24·0	$6\frac{1}{2}$	112	12	383
$3\frac{1}{4}$	28·1	7	130	13	450
$3\frac{1}{2}$	32·6	$7\frac{1}{2}$	150	14	522

It is essential, too, that the bearings should be arranged as close as possible on each side of the main pulley or gear wheel. If the number of pulleys is unusual, or the work excessive, the bearings must be spaced more closely than the formula gives. Or if this is impracticable the size of the shaft must be increased.

No one we presume ever uses wrought-iron shafting now. Steel is more economical, because, being stiffer and stronger, a lighter shaft in steel will do the work of a heavier one in wrought iron. It is economical to use shafts as small as practicable, because their friction is less than that of larger ones, and the friction of shafts causes a considerable loss in power. No rule can be given, but it may vary from 10 to 20 per cent., estimating the shaft friction only, without reckoning that due to belting and pulleys, which would double the above figures.

Friction varies widely with the degree of efficiency of the lubrication adopted. The Unbreakable Pulley & Mill Gearing Co., Ltd., use the following formula:—

Let P = power expended in overcoming friction, expressed in foot pounds per minute.

w = the coefficient of friction, say ·06.

W = the load carried by bearings in pounds.

d = diameter of shaft in inches.

R = number of revolutions per minute.

$\pi = 3{\cdot}14159$.

$\frac{\pi}{12} = {\cdot}2618$.

$0{\cdot}6 \times {\cdot}2618 = {\cdot}015708$.

Then

$$P = wW\frac{\pi}{12}dR = \cdot06W\cdot2618dR = \cdot0157WdR.$$

By working out different sizes of shafts by the formula $\cdot0157WdR$, it may be shown that a $2\frac{3}{4}$-in. shaft absorbs 30 per cent. more power than one $2\frac{1}{2}$ in. diameter.

An element of economy in line shafting is to reduce diameter in a long shaft from the end where the power is first taken, to the farther end where the demands on the shafting are the lowest. Successive lengths from bearing to bearing may thus be reduced, preferably by equal fractions, as $\frac{1}{4}$ in. The couplings

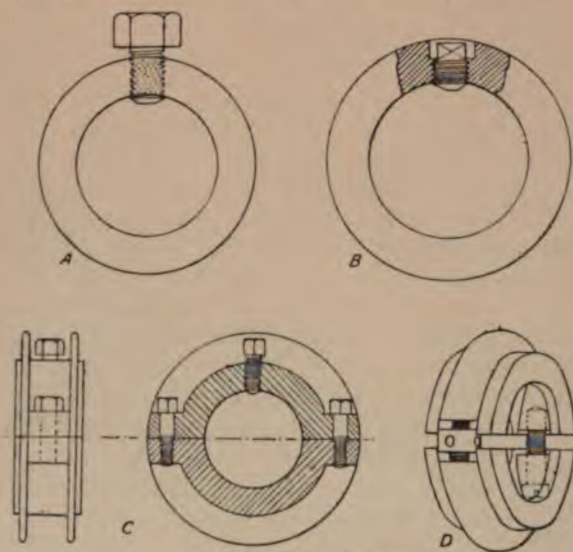


Fig. 119.—Shaft Collars.

uniting adjacent shafts should then be of one size of bore, and the end of the larger shaft be stepped down to the size of the smaller one.

There are limiting sizes to shafting, which sizes vary with diameter. Shafts less than 6 ft. in length are charged extra, and also shafts exceeding 20 ft. Railway companies charge shafts exceeding 18 ft. in length as 2 tons in weight. The best shafts are made of open-hearth steel. Their tensile strength is from 27 to 32 tons per sq. in. of area, with an elongation of 20 per cent. in 8 in. Bessemer bars are inferior to open-hearth.

Collars.—The function of these is to prevent endlong movement of shafting, and to retain loose pulleys in place. The solid collar, Fig. 119, A, pinched on the shaft with a set-screw is the worst form, because, like the flanged coupling its fit must be exact. The projecting set-screw is also very dangerous. In some cases the head of the set-screw is sunk into a recess, as at B. This avoids danger, but the other objection remains. Some collars are split but with bolt heads still projecting. In others the heads lie in recessed portions, gripping through flanges, C. The best form probably is the Trier, Fig. 119, D, in which the halves are united on one side by screws, right and left handed, with a central boss having holes for the insertion of the tommy. On the other side a cheese head screw is inserted having its head sunk in a recess. This is maintained in a condition of tension by the tightening of the right and left hand screw, and therefore does not slacken back.

Erecting Shafting.—The methods of doing this depend partly on circumstances, chiefly on whether it is being done in a new shop, or in an old one where the floor is occupied by machines and benches.

When there is a clear floor area it is better to lay out the positions of the lines of shafting and of bearings on the floor, plumb underneath the positions which they have to occupy overhead. It is easy to do this, starting with the location of the main shaft, from which the others can be laid out parallel, or at right angles as required. Straight lines are marked from a chalk line strained, and in case of obliteration, a few nails are driven in to mark the location of the lines and of the bearings. Afterwards the same positions are marked on the beams overhead by dropping a plumb line thence, and adjusting it till the bob is right over the lines on the floor. The work of erecting the bearings then proceeds.

The foregoing only gives the correct relations in plan. To ensure horizontal truth, two methods are available. Blocks of wood are nailed down to the floor at convenient locations under bearings, and levelled with a straightedge and spirit-level. They are corrected carefully by the removal of shavings from the higher

:ks, until the surfaces of all are in the same izontal plane. Then these form a basis for levelling of the bearings and shafting, taken direct measurement therefrom by means of a cut to the exact length corresponding with height selected, say to the feet of the bear- s, and then later to the bottom side of the fting. The bolt holes for the bearings can

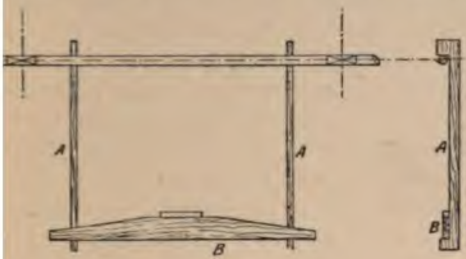


Fig. 120.—Erecting Shafting.

narked directly from a templet laid against underside of the beams. The templet will e a hole drilled centrally, to be laid on the tre plumbed on the beam, and then the bolt es are marked through holes bored in the plet. Some subsequent correction is neces- y. This is done in both directions. In plan, s effected by looping a plumb line around shafting, and adjusting if necessary until the nt of the bob comes exactly over the centre on the floor. In the hori- tal direction, the spirit-level is d, laid on a parallel straight- e resting on the shouldered s of two rods hooked over, l dependent from the shaft, . 120.

When centre lines have to be rked at right angles on the r the square is not accurate ugh. Then a triangle is drawn ing a length of 3 ft. marked ng the base line, starting from the point where centre of one shaft has to intersect that of other. From this starting point mark off ength of 4 ft., and from the 3 ft. length, a gth of 5 ft. A line drawn from the point of ersection of the 4 ft. and 5 ft. lengths to the rting point will be at right angles with the e. Or, if the base line can be extended to both sides, the method of raising a perpendicular through the intersection of equal arcs can be adopted.

When a shop is occupied with machines, new shafting can be erected in another way, though a more roundabout one. The centre line of the shafting can be snapped with a chalk line strained along underneath the beams. A straightedge and level are used to test the horizontal truth of the shafts, and a straining line of wire pulled taut checks the lateral alignment, measurement being taken thence to the edges of the lower half bearings while open.

Wall brackets are fitted by essentially the same methods as those just described as suitable for plummer blocks or for hangers. Lines, Fig. 121, A, can be plumbed and measured on the wall, and a templet, B, set thereby from which to mark the bolt holes on the wall.

Countershafts.—The function of these is to take the power from line shafts and deliver it to the machines. The necessity for their use lies in the fact that the rate of revolution of a line shaft is constant, while that of the machines driven therefrom, with very few exceptions has to be varied largely, both in the case of different machines, and in the same machine at different periods. Also one, two, or more countershafts may be required for different operations on a single machine, as on some grinders.

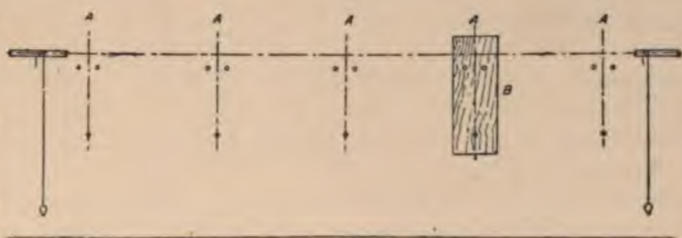


Fig. 121.—Locating Wall Brackets.

The speed of a countershaft is regulated by the relative sizes of the pulleys on line and counter. Frequently it may have two speeds, obtained through two sets of pulleys. In a set, one pulley is loose on its shaft for the belt to run idly on, the other is fast for the driving to take place through. To vary the speed between the counter and the machine, stepped cone

pulleys are used, with the steps reversed in direction. Or in some cases, notably in many of the recent high-speed lathes, the belt pulley is single-stepped, and the changes in speed are made through gears in the lathe head.

Countershafts are made in two designs, the

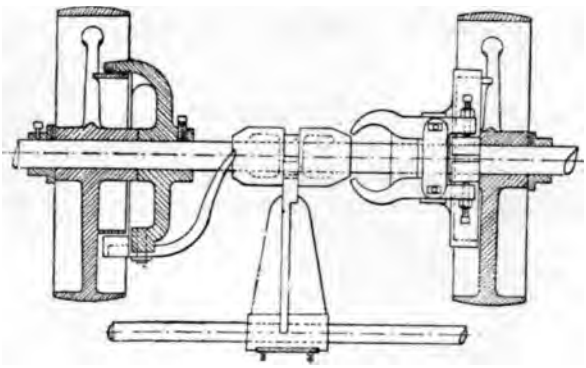


Fig. 122.—Friction Countershaft.

commoner type in which the belt is shifted between fast and loose pulleys, and the friction or clutch type in which the belts are made to drive or run loosely by the grip of the friction clutches, as in Fig. 122. Many of these are made now, not only for ordinary machine driving but also for main line shafts. *See* **Shaft Couplings** for examples.

Countershafts have to fulfil three functions. They may drive at one speed, or at two speeds, but in the same direction; or they may run at two speeds, one for driving, the other for reversal. There are different ways of effecting these movements.

Single-speed Countershafts.—The common form of this design is shown in Figs. 123, and 124, A. The fast and loose pulleys are belted from the main shaft, and the stepped cones drive to the machine. In the case of some wood-working machinery, as circular saws, the necessary speed for the saw spindle cannot be obtained with one countershaft because of the great disparity which would occur in the sizes of the pulleys. Speed increase is then divided between two counters. The one-speed counter is more common than any other. Frequently the fast pulley is ¼ in. or ½ in. larger than the loose one, so that the belt runs tightly only when work is being done. By this device the strain on bearings and countershafts is lessened.

Two-speed Counters.—When the driving is in the same direction there are two ways in which the relative speeding is obtained. The older plan was to have all pulleys on the line shaft of uniform diameters, and to make the differences on the counter pulleys, Fig. 125. The usual method now is to make the difference on the line shaft pulleys, and then the counter is like Fig. 124, B. The middle one is the fast pulley, and the flanking ones are loose. The pulleys are two belts wide. In Fig. 124, C and D, they are one belt wide, these being alternative arrangements of Fig. 125.

When driving and reversal are embodied, then open and crossed belts may be used as in Fig. 124, E or F. Or the sets of pulleys may be separated as in G, H, or J. In E and F the line shaft pulleys must be varied, if reversal is to be more rapid than driving.

Long drums are essential when a belt has to be traversed, as in cylindrical grinders, and other machines with traversing heads. Countershafts often carry pulleys for belting to the feeds,

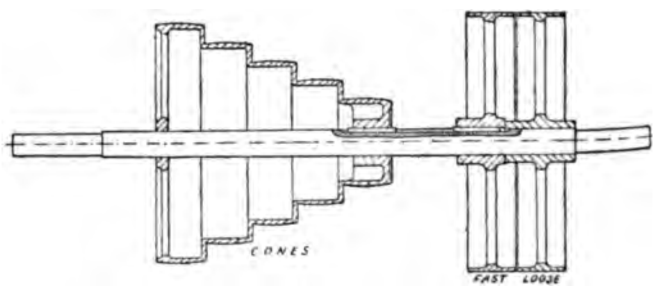


Fig. 123.—Single-speed Countershaft.

to the traverse of tables, and for actuating pumps for lubrication.

Shaft-Straightening Machine.—Employed for straightening shafts preparatory to turning them in the lathe. The usual form is that of two supports placed a little distance apart, with a ram midway, to press upon the shaft and force it, either by screw, or hydraulic

pressure. The machine may be fixed to a bench, or it may be attached to the lathe. One of the hydraulic types much resembles the rail bender. Another handy pattern is fitted with wheels to run along the lathe bed, and so be capable of acting at any required position on the shaft, which is left on the centres. It is turned at intervals to test the truth, a piece of chalk being held at various places to indicate the parts that are eccentric.

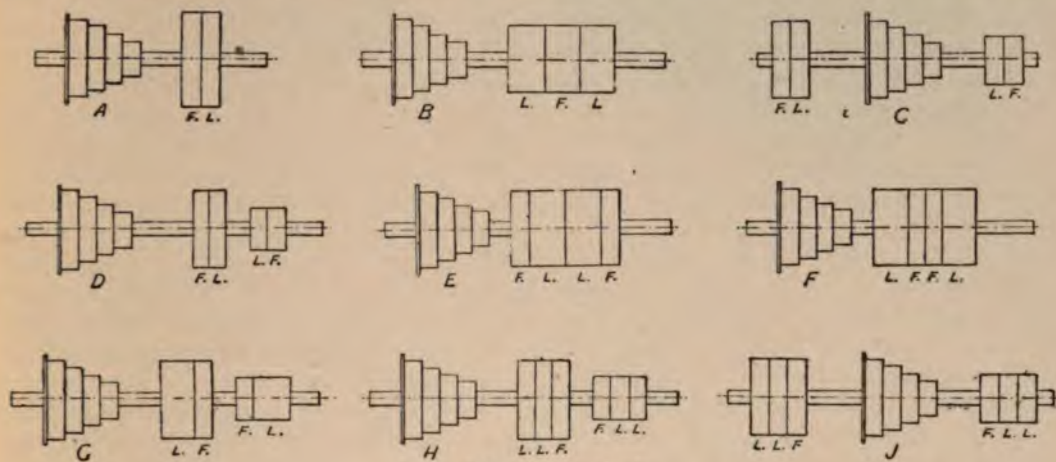


Fig. 124.—Countershafts.

Shaft-Turning Lathe.—A special type of lathe the sole function of which is that of turning shafting, usually at one traverse of the slide rest. The bed is long, and an arrangement is included by which both ends of the shaft can be driven in turn, to leave them free for the passage of the tools right to the end. The tools are multiple, to rough and finish at one pass, either three or four being employed. A steady rest is necessary to prevent the shaft from springing, or sagging by its own weight.

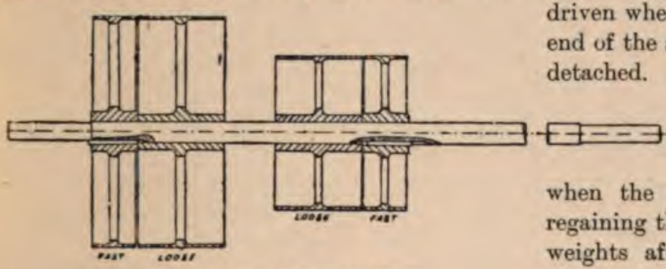


Fig. 125.—Two-speed Countershaft.

Fig. 126 shows a lathe by the Société Alsacienne de Constructions Mécaniques, of Grafenstaden. The height of centres is 380 mm. ($14\frac{15}{16}$ in.) and shafts up to 150 mm. ($5\frac{7}{8}$ in.) by 9000 mm. (29 ft. $6\frac{3}{8}$ in.) can be turned. The bed A carries two heads, B and C, which are similar excepting for the fact that C is adjustable along the bed by rack and pinion, to suit various lengths of work. The driving of each head spindle is from the cones and back gear at D, actuated from the countershaft E. D drives a shaft F lying at the back of the bed, and this shaft connects up to each of the spindles through four gears, when clutches at G and H are slid into engagement. The spindle of C is only driven when it is necessary to turn right to the end of the shaft at B, the carrier thereon being detached. Double pin driver plates are employed. The shaft F is supported by tumbler bearings at J and K, which are pushed downwards when the carriage L meets either of them, regaining their position by means of the balance weights afterwards. The self-acting feeds of the carriage are derived also from F, through worm gear, thence by a cross-shaft to gears under the apron, where a pinion engages with the rack on the front of the bed. Hand gear is provided for the purpose of effecting adjustments. An automatic shipping gear is fitted, to stop the rest at any predetermined position; the shaft M has adjustable dogs upon it, and

as these are struck by the rest moving in either direction the lever N is thrown over, and pulls

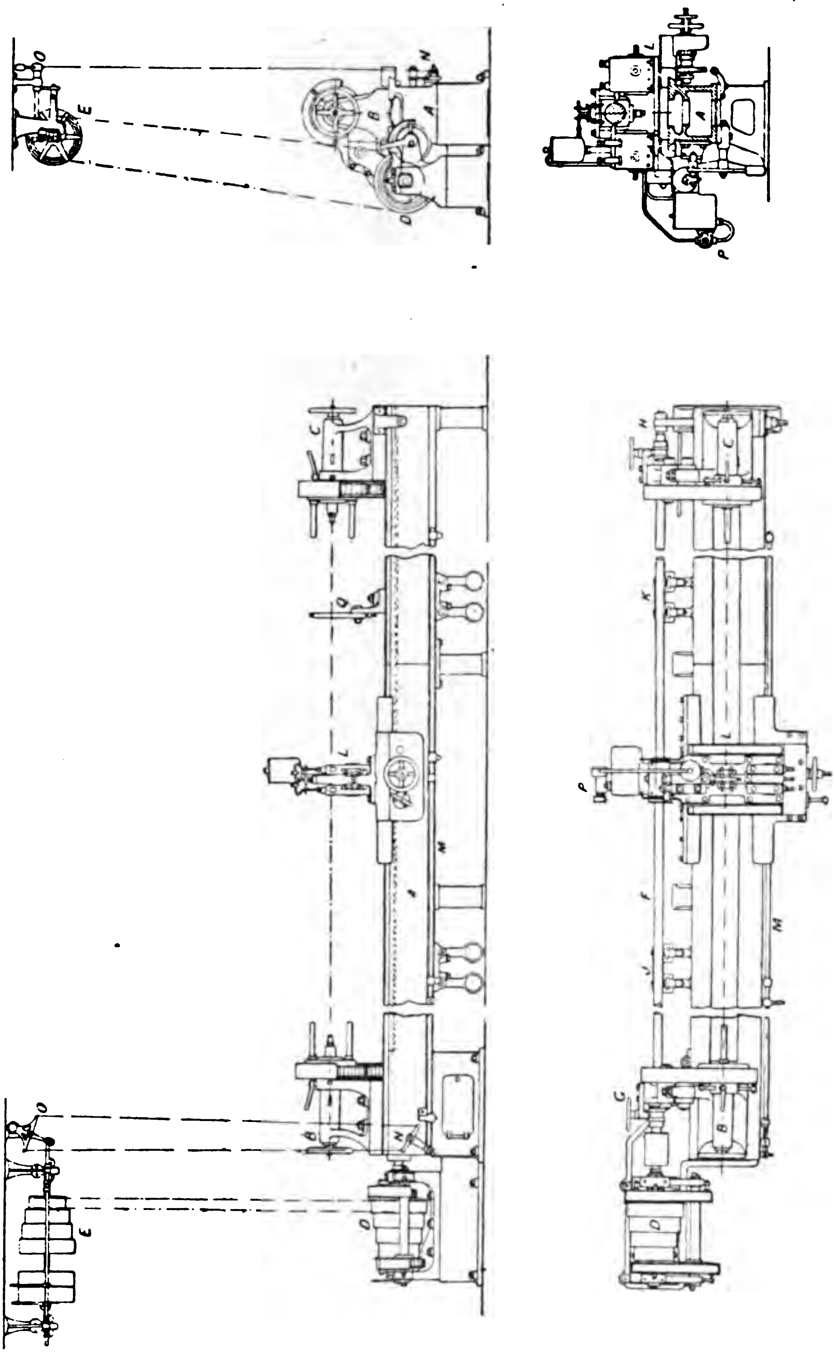


Fig. 126.—Shaft Turning Lathe.

cords connected to a similar lever O on the countershaft, striking the belt, and stopping the lathe. The same effect is produced by th attendant moving the rod M by hand.

The carriage cross-slide supports three tc holders, two opposite each other for roughi

tools, and one alongside at the front for finishing. Three squared spindle ends at the front provide for adjusting the tools for diameter. The back rest screw is operated through spur gears, driving from the central spindle, which has to be placed to one side on account of the next screw. A pump, P, supplies ample lubricant to the tools, each one being provided with a pipe above. The steady rest Q is duplicated both in front and behind the carriage on long shafts.

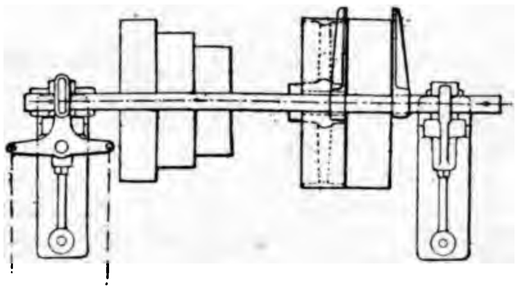
Shaping.—Signifies the tooling of short pieces of work in a reciprocating type of machine tool. There is a large volume of such work in a machine shop, which cannot economically be put on a planer of long stroke. Shaping is done on horizontal faces chiefly. Vertical faces can only be dealt with if not very deep; and though the length which can be shaped is limited to the length of stroke of the machine, the width is only limited by the working length of the bed, *i.e.*, that over which the tool ram or the knee can be traversed. Circular shaping, both convex and concave, can be done. Slotting is practically nearly identical with shaping in regard to the class of work done, the principal difference being in the horizontal and vertical movements respectively of the tool. The milling machine has appropriated much of the work of the shaper.

Shaping Machines.—Machine tools of the reciprocating group, which differ from planers in their relatively shorter stroke, which rarely exceeds from 15 in. to 24 in. in length, while in the smaller machines the stroke is limited to 6 in. or 8 in. A shaper comprises a bed, supported on feet, or going down to the floor, and carrying the shaper arm above, and the work table, of knee form, on one vertical face. This knee is provided with horizontal and vertical adjustments. The work is fixed, and the tool arm reciprocates over it. The vertical feed is always imparted to the tool box, the longitudinal or lateral feed is imparted to the tool arm through its carriage in machines of large and medium size, but in those of small dimensions, to the knee. Machines have one tool arm, and one knee; or one tool arm, and two knees, or they are *double-headed*, each knee having its own head and arm. Movements may be by hand, or self-acting. The ram usually has a quick return motion. Provision exists for shaping plane surfaces, and convex, and concave forms. We will consider the leading elements in turn.

The Bed, and Tables.—The bed is of box form, and whether it is supported on feet or not depends mainly on manufacturers' ideas. But generally the double-headed shapers in the smaller sizes only are carried on feet, though there are examples of massive shapers so built. The feet are spread very much at the base to afford steadiness to the overhanging tables, and under heavy cutting. But a box bed reaching to the ground is generally preferred in shapers of all dimensions, the base being spread widely. In the smallest shapers the bed is a pillar of nearly square section in the horizontal plane. In the larger ones it is of oblong form. The front face of the bed has machined facings running horizontally, to receive the carriage or saddle on which the work table or knee is fitted. The saddle slides horizontally on the facings for lateral adjustment, and feed, the table slides vertically for adjustment in that direction, which is effected by a screw actuated by bevel gears from a handle at the front. The saddles are clamped by tee-head bolts sliding in tee grooves in the facings, and the tables are clamped similarly to the saddles. In some designs the saddles fit by vee'd edges to the bed facings.

The tables are generally of angle plate form, to permit of bolting work to the top and side. Some tables form three sides of a rectangle, to give two opposite vertical faces for bolting to. Tee-head grooves are made in each work face to receive tightening bolts. In a few shapers the table is made to swivel by worm gear, and is graduated to permit of shaping work to definite bevels.

The Tool Box, and Ram.—The cutting tool is carried in a box at the end of an arm or ram, which is reciprocated in guides on a traversing saddle, moving on ways on top of the bed (the *traversing head* type). In many of the smaller machines the ram does not traverse, but that movement is imparted to the work table. Then the ram reciprocates only on top of the bed. In the first case the tool has three movements;



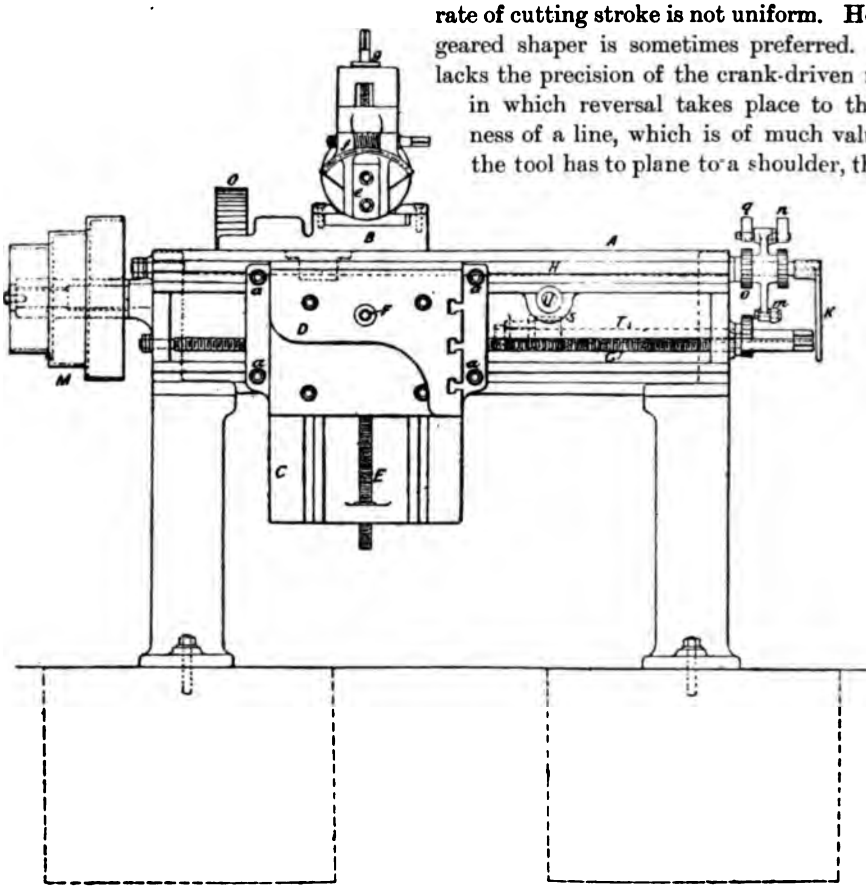


Fig. 127.—8-Inch Shaper. (Front Elevation.)

the longitudinal traverse, giving the lateral feed, the reciprocating stroke, giving the length of cut, and the downward movement, giving the feed for depth. In the second case the tool has the last two movements only. Angular cutting can only be done by adjustment of the work. Circular cutting is done in the case of concave surfaces by an arc movement imparted to the tool box, by worm and quadrant gear, which, however, is not included in all machines. Convex work is cut by means of an arbor rotated through an arc, or a complete circle. The tool slide is fed downwards by hand, or in many machines a power feed is included.

The method of operating the tool arm is generally by means of the Whitworth link, situated at the rear of, and generally below the ram. The free end of the link is connected to the ram by means of a rod. The length of stroke is capable of variation by altering the position of the die block. In this design the rate of cutting stroke is not uniform. Hence the geared shaper is sometimes preferred. But it lacks the precision of the crank-driven machine in which reversal takes place to the thickness of a line, which is of much value when the tool has to plane to a shoulder, though of less value when the tool may overrun the work as in planers. In the larger link-driven machines, the link is situated outside the fram-

ing; in the smaller ones, of what may be termed pillar type, the link is within, and takes a different form, described under **Quick Return**.

Speeds, and Feeds.—Speeds for driving are obtained from stepped cones driven from the countershaft, four steps being usually included, giving four speeds. The feed is through a screw lying centrally between the ways of the bed, and this is driven through spur gears, by which the rates of revolution of the cone pulley are geared down through ratchet feed wheels. A short shaft which carries the disc for quick return also carries a slotted feed disc. There are thus several rates of feed for each speed of the stepped cone. The feeds may be set by a divided hand-wheel.

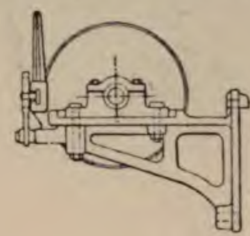
The quick return is derived from the same shaft which carries the feed disc. The disc on the shaft is slotted to receive the die block or nut, which slides in the slotted crank arm. The cutting stroke takes place when the block is on the upper half of its circular path, the quick return stroke when it is on the lower.

The down feed to the tool box is generally effected by hand, with or without micrometric arrangements, except in the larger, and more complete machines. A ratchet and pawl are fitted to some of these to effect the movement from the motion of the ram. The quadrant fitting for internal curves is also fed by hand, or is self-acting by a ratchet and pawl.

The arbor for supporting work which is being cut to external curves is rotated by worm gear actuated by ratchet and pawl from a slotted disc, which gives feed adjustments. This arbor is located about centrally on the bed, just below the ways. Some shapers are made with a constant speed belt drive, the variations in speeds being effected in a speed gear box, a method which is in harmony with modern tendencies, more frequently seen in machines of other types, as milling machines and lathes.

Miscellaneous Features—Geared Shapers.—In these the quick return is effected by a pulley distinct from that used for cutting, and being smaller than the latter. A train of gears drives to the ram, which is driven by a rack. In the Hendey shaper of this type, the pulleys are actuated by a friction wheel moved into contact with the interior of either of the pulley rims. In the Walcott geared shaper two cutting speeds are provided for by two countershaft speeds, one for steel, the other for cast iron. In the Hendey machine the driving pulley has two steps.

Elevating Rail Design.—In the Cincinnati design the table has no elevating movement in itself, but it is raised and lowered along with the vertical ways which form a cross-rail, gibbed to vertical guides on the front face of the pillar. The rail is moved vertically with



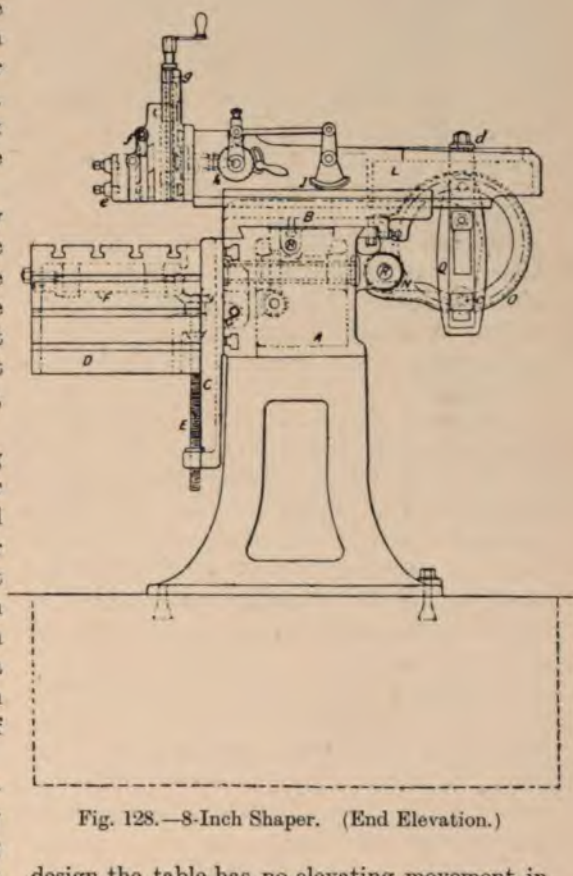


Fig. 128.—8-Inch Shaper. (End Elevation.)

a screw, and the table moved horizontally also with a screw.

Modified Tables.—The Cincinnati designs include a table the faces of which occupy all four sides of the rectangle, three being fitted with tee grooves. There is a revolving table turned by gears through an angle of 90° in each direction. Another form of table is hinged to tilt forwards from the bottom. In a third, an extra tilting top is fitted to ordinary tables. A revolving table fitted with a tilting top carrying a vice is useful for cutting dies and moulds.

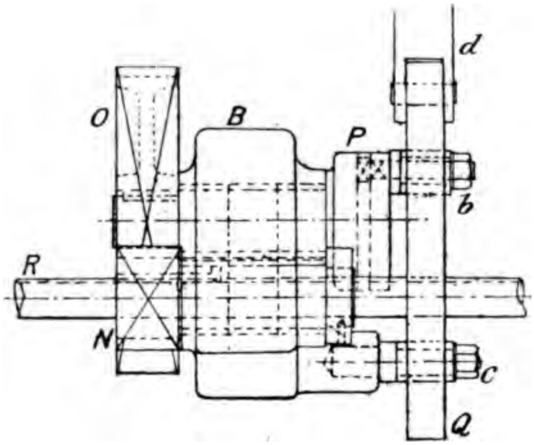


Fig. 129.—Ram Driving Gear.

Draw-Cut Shaper.—This is made by the Morton Co., its feature being that the tool cuts on the inward stroke. The stress is purely tensile and less vibration results than in the ordinary type. Some minor modifications are rendered necessary, such as pivoting the tool block to relieve the pressure on the forward stroke instead of on the backward. The ram is rack driven.

Examples of Shapers.—Figs. 127 to 133 show an 8-in. stroke shaper by Cunliffe & Croom, Ltd., of the type in which the feed is imparted to the ram, the knee being adjustable by hand, but remaining fixed during cutting. The following are the principal details:—

The bed A is mounted on two legs, and has ways planed on top for the saddle B of the head, and on the front for the saddle C of the knee D. The latter has two tee-grooved faces for the attachment of work to, and is raised and lowered by the screw E actuated through mitre wheels, by a horizontal shaft F from the front, turned by a crank handle. The tee-head bolts a, a, a, a, clamp the saddle against the face of the bed when vertical faces are being tooled, and when working on horizontal faces. The table is fed transversely by the screw G in a nut on the back of the saddle C.

The saddle B of the ram is fed by a screw H in the nut J underneath, by ratchet gear seen in Fig. 127 and separately in Fig. 131. For hand adjustment the crank K, Fig. 127, is utilised. The ram L is reciprocated in B to which it is fitted by square gibbed edges. The driving of the ram takes place in the following manner:—The cone pulley M driven from the similar pulley on the counter has a spur pinion N on its shaft (compare with Fig. 129), which drives the wheel O. The pinion N is splined to the shaft to traverse with the carriage B. The wheel O is keyed fast to its spindle which is carried in a bushed lug in the carriage. A slotted disc, P, is attached to the opposite end of the spindle, across which the pin and block b can be adjusted. It slides in the link Q, which rocks in the pivot C in an extension of the carriage B. The link is not pivoted directly, but has a slight amount of sliding on the pivot,

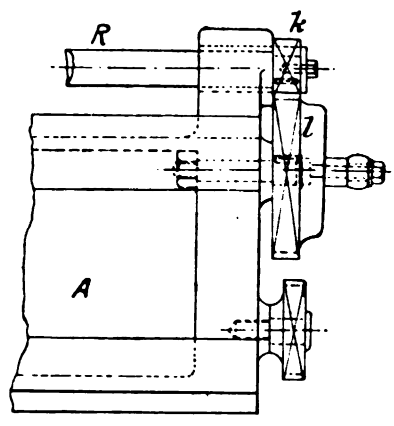


Fig. 130.—Feed Gears.

in order to avoid an arc movement where it is connected to the block d, which transmits the slow cutting and quick return movement to the ram. The adjustment of the length of stroke of the ram is effected by changing its position in regard to this block, which is clamped anywhere in the slot provided in the ram, as shown.

The tool box at the end of the ram L is of the usual type fitted to shaping machines, but with the addition of an automatic down feed.

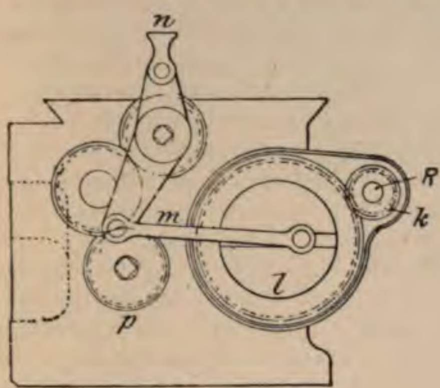


Fig. 131.—Feed Gears.

The tool holder *e* is a clapper, to relieve the tool on the back stroke. It is swivelled through an arc by the worm gear at *f*, comprising a worm and a quadrant. The screw *g* imparts the down feed. The crank handle above effects the feed by hand. A device seen in front of the ram, Fig. 128, derives it from the movement of the ram itself. It is a ratchet wheel, and bevel wheel which communicate intermittent motion through bevel gears to the feed screw *g*. The ratchet movement is derived from the friction quadrant *j*, rocked to and fro in contact with one of the gibs B by the reciprocation of the ram.

The feeds are derived from the splined shaft R driven by the cones M, and are seen at the right-hand end of Fig. 127 and partly enlarged in Figs. 130, 131. A pinion, *k*, at the end of R drives a slotted feed disc, *l*, through teeth on its periphery, and this, by means of a lever, *m*, and pawl, *n*, actuates the screw H through the nut J, Figs. 127, 128, for the longitudinal traverse of the carriage.

The circular shaping attachment is indicated at S, in the general views, and in detail, Fig. 132. It comprises a worm on the shaft T and a worm wheel, S, on the arbor U. The driving takes place from the wheel O loose on the shaft H, through an idler to the wheel *p* on the end of the shaft T. The amount of feed is regulated by the ratchet *q*. The arbors of various sizes and lengths supplied, and interchangeable in the bed are seen in Fig. 132. The machine vice is shown in Fig. 133.

A heavy machine of 12-in. stroke is shown by the next Figs. 134 to 139, being one by Tangyes, Ltd. A stiff box bed, A, goes down to the ground. A deep saddle, B, clamped to tee slots on the face of the beds carries the knee C, which has two tee-grooved working faces. The saddle is barred along by means of a rack, *a*, cast in the face of the bed. The knee is raised and lowered by hand by the screw D, and bevel wheels from the horizontal shaft E. The ram saddle F is fitted with vee'd edges, and a gib to the top of the bed, and is traversed by the screw G, which is double-threaded. The ram H fits with square edges and strips, and is gibbed. Its method of operation is as follows :—

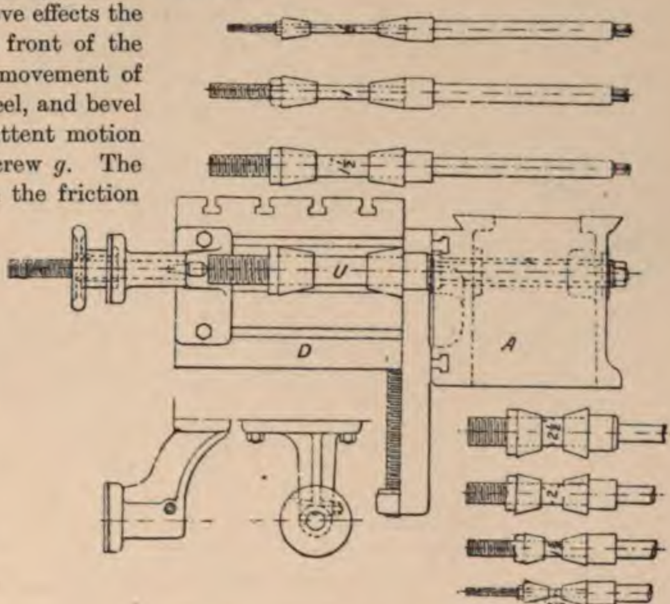


Fig. 132.—Circular Shaping Arbors.

The cone pulley J seen in the front and rear views of the machine, Figs. 134 and 136, driven from the countershaft, Fig. 137, drives the splined shaft K, along which the pinion L slides. The

latter is confined by a bracket which forms a portion of the carriage F, so travelling with the latter. L drives the wheel M on a journal which has its bearings in the bracket just mentioned. At the other end of the journal the

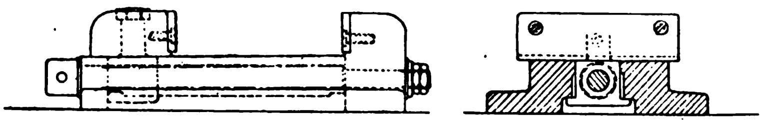


Fig. 133.—Shaper Vice.

slotted disc N carries the adjustable block O, which slides in the link P pivoted at *b*, thus providing the means for slow cutting and quick return to the ram H, through the connecting rod Q. The position of the ram is regulated by the block R moved along the slot in the ram, Fig. 138.

The longitudinal feed of the saddle F by the

shaft, and actuating the link X, which actuates a ratchet pinion on a shaft passing along within the bed, carrying a worm at its farther extremity turning the worm wheel Y, and its sleeve, into the end of which the cone mandrels Z of different sizes are fitted (compare with the enlarged section in Fig. 139). The tool box is provided with a swivel motion indexed for shaping internal curves.

Fig. 140, Plate VII., is a pillar shaper with geared friction drive, embodying pulleys for open and crossed belts, with a cone clutch between. The arms of the clutch are elastic, so that the shock of engagement is minimised. The clutch is slid to right and left alternately through levers actuated by the motion of the ram, which carries adjustable stop

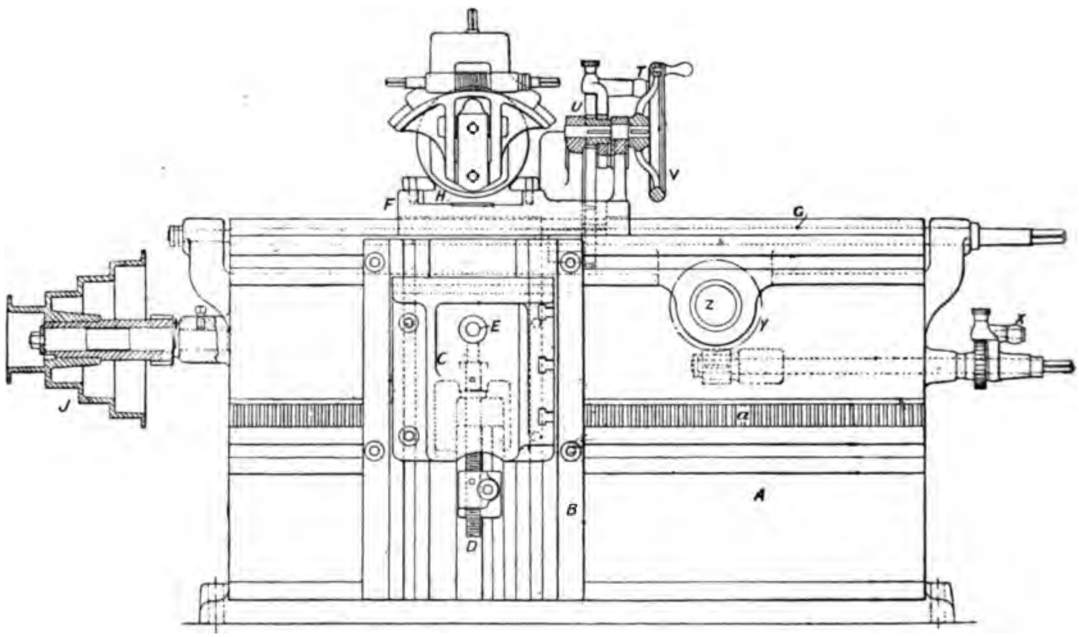


Fig. 134.—12-Inch Shaper. (Front Elevation.)

lug *c* is accomplished from the feed disc S and rod T, engaging a pawl with the wheel U, engaging with another wheel fitting on the screw G. Hand adjustment, or hand feed is provided by the wheel V. The circular feed is derived from the slotted disc W, driven from the splined

dogs, the position of which may be altered while the machine is running, to lengthen or lessen the stroke. As the ram is fixed laterally, the feed motion is given to the table, by hand, or automatically by the ratchet device seen. There is a hole through the frame, beneath the

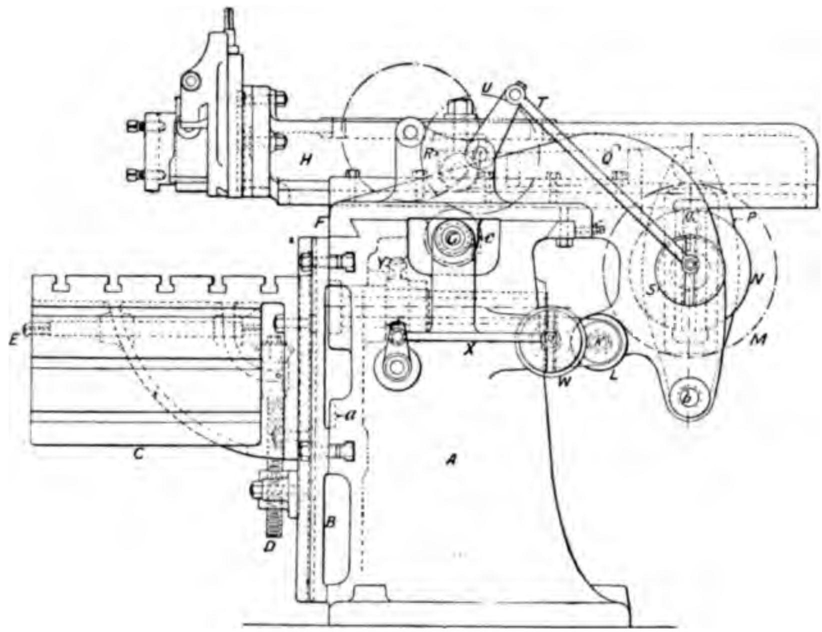


Fig. 135.—12-Inch Shaper. (End Elevation.)

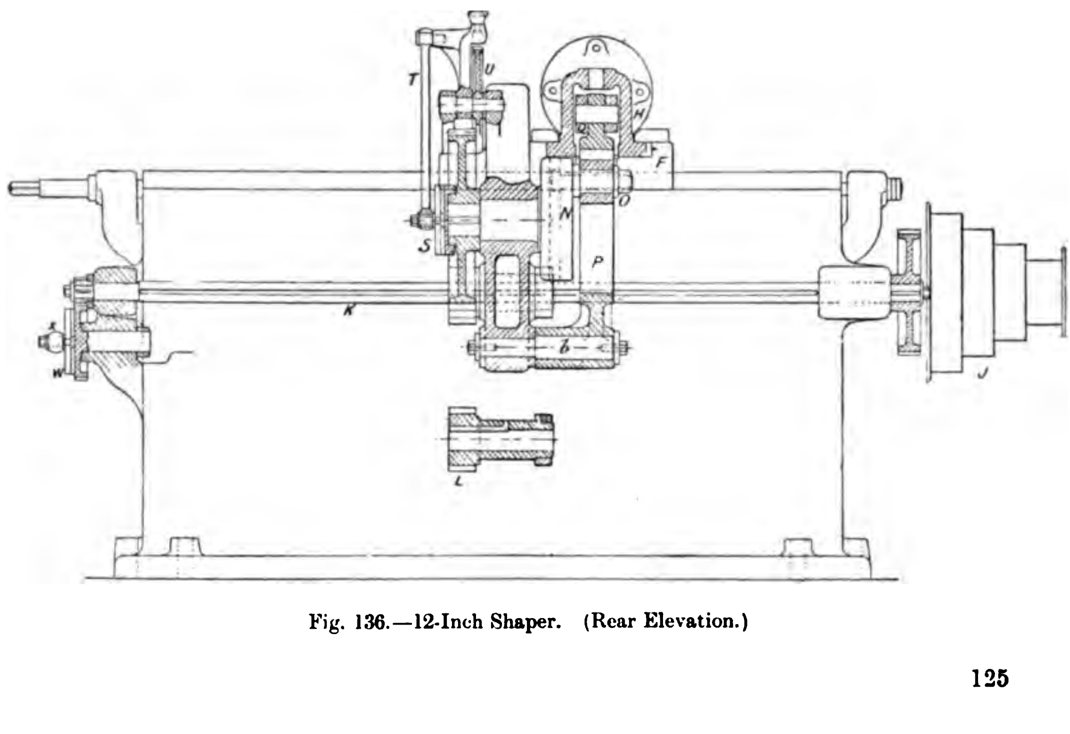


Fig. 136.—12-Inch Shaper. (Rear Elevation.)

ram, so that shafts of any length may be passed through and keyseated.

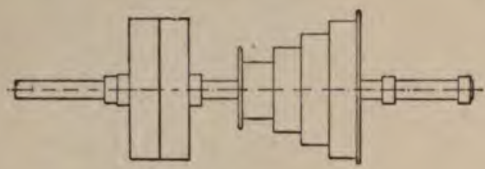


Fig. 137.—Countershaft.

Fig. 141, Plate VII., illustrates an American type shaping machine of 26-in. stroke. The ram is driven by Whitworth motion, and eight speeds are obtained through the four-stepped cone, with a two-speed countershaft. The saddle is adjustable along the bed by a rack and pinion, and a self-acting feed is imparted by ratchet mechanism in the usual manner. There is also a ratchet arrangement for the circular arbor feed. There are two tables, one having three tee-slotted faces for holding work, the other having only a horizontal face. Both the saddles carrying the tables are adjusted along the face of the bed by racks and pinions operated with a ratchet lever, and the tables themselves are moved up and down by screw and handle at the front. The index centres seen on the ground can be mounted on the table face.

When two heads are mounted on one bed, the result is practically two independent machines, with the advantage that a single attendant can manage both. Fig. 142, Plate VIII., shows a heavy double-headed machine of 20-in. stroke. Each saddle is driven by its independent gear, including a three-stepped cone, and the choice of two ratios of spur gears, either of which is thrown in by sliding with a clutch handle. The Whitworth motion actuates the rams. There are self-acting feeds for traverse, and for the vertical, and segmental motions of the tool boxes. The three saddles carrying the tables are moved laterally by a pinch bar inserted through a slotted angle plate at the edge of the table, and bearing against the ribs cast at the front of the bed. Handle motion and a screw are used to elevate the tables, which are clamped against their saddles by bolts coming to the front.

Sharpening.—This is often a distinct operation from that of grinding cutting tools. It is always so in those used for wood-working, but in many for metal-work the two operations are combined in one. In all cases where heavy

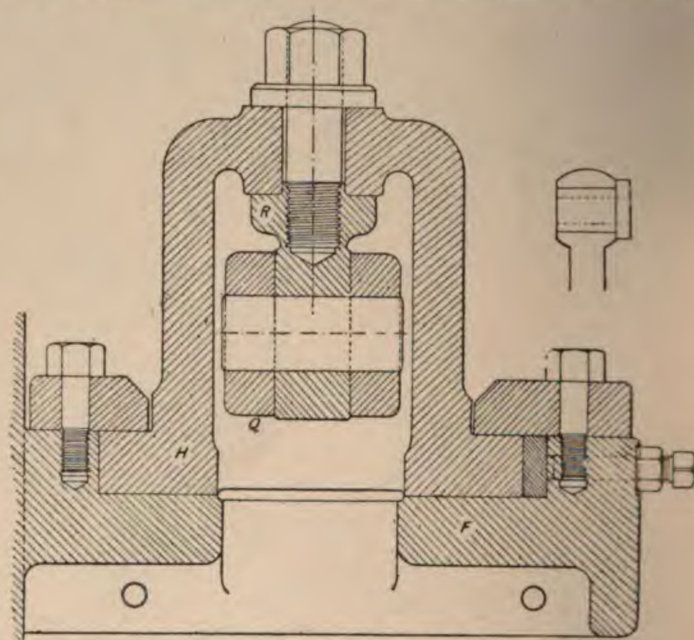


Fig. 138.—Section of Ram.

roughing only is being done, the metal cutting tools are left as ground, but for fine finishing

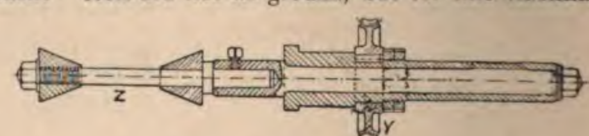


Fig. 139.—Circular Arbor.

with light cuts the tools are frequently finished on a hone. This is done in broad finishing tools, spring tools, round nose and radius tools, and

Fig. 93.—Sewage Plant at Sutton.

Fig. 140.—Pillar Shaping Machine.
(Ludwig Loewe & Co., Ltd.)

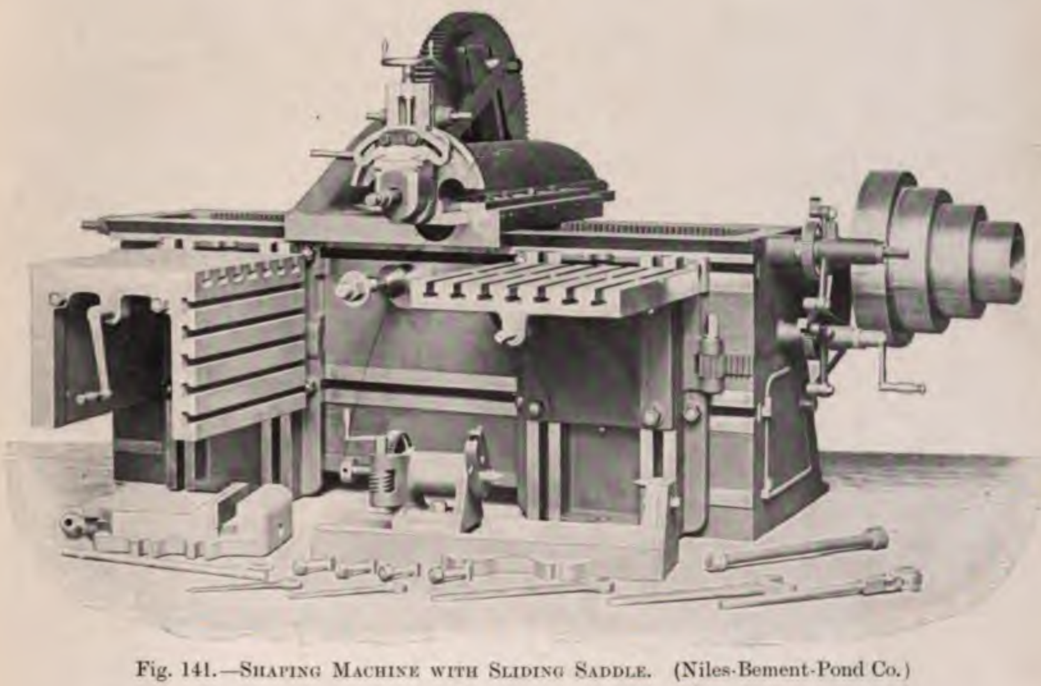


Fig. 141.—Shaping Machine with Sliding Saddle. (Niles-Bement-Pond Co.)

To face page 128.

others of similar character, the operations of which approximate more nearly to scraping than to cutting. In some cases the smoothness of edge which follows sharpening is obtained by grinding with wheels of fine grade, removing extremely minute amounts. It is so in milling cutters, and in many machine cutters for wood.

Sharpening tools for wood-working invariably follows grinding. The latter removes material in quantity, the former imparts a fine edge. After repeated sharpenings, the angle of the tool becomes increased or *thickened*, and then it has to be reduced by regrinding.

The art of sharpening consists in rubbing the opposite faces of the tool in turn upon a hone of suitable grade, using oil to render the operation easy, and to lessen heating. If a tool has one face wholly flat, and the bevel wholly on the other, then the actual reduction must be made on the bevelled face only. This is rubbed down until a *wire edge* of metal is turned over, and this is then turned back by a slight rubbing of the flat face, held *quite flat* on the hone. This may be repeated two or three times in succession.

Shearing.—A shearing force is one which operates in the plane of a cross section. Its intensity is equal to the shearing force s × the area of the section. But a simple shearing strain occurs only when the force is exercised in a single plane. A rivet properly closed is an example of such a strain. But if the rivet fits loosely, the strain is no longer that of simple shearing, but includes bending also.

A beam fixed at one end and loaded at the other is subject to both shearing and bending. But as the latter form of loading is greater, the former is not considered in calculations. It is demonstrable that unless there were an upward shearing resistance between the loaded and the fixed end, the beam would drop. The shearing load at any part of a beam equals the resultant of all the parallel forces acting on the beam on one side of that section. *See* **Beam**.

Shearing Machines.—A large group in which the action is that of a pair of shears operated by power. As the shears are often constructed with a punch in one framing, the general type is described under **Punching Machines**. The top shear is actuated either by a cam, or a lever, or by hydraulic power similarly to the punching slide. But though the majority of machines are thus made double-ended for the convenience of the general shop, large numbers are designed single-ended for shearing only. These include the large types used in steel works, in ship and bridge yards, besides the special designs used for cutting off bars, angles, channels, and other sections, and those employed in sheet metal working, including the rotary shears.

The framings of shearing machines follow the same lines as the punching, or combined punching and shearing machines do. They are usually of cast iron, which if rigidly built is suitable enough, but many framings have failed by fracture through the gullet, following a long period of service. Of late years the practice of building frames of plate and angle has extensively developed, and large numbers of these are now in operation.

The single-ended machines are actuated in various ways, as by belt on fast and loose pulleys, driving through a heavy flywheel and pinion to a wheel on the eccentric shaft, thus reducing speed with gain of power, and providing a store of energy to carry the shear through the plate. The shear blades are arranged either in front of the gullet, or at one side. In the first there is a limit to the length which can be cut, in the second there is not. But the width is not limited in the first, while it is in the second. Each has its own special utilities.

Many of the heavier machines are driven by their own independent engines bolted up to the framings. This is advantageous in shops and sheds where the machines are not located in lines parallel with line shafts. The substitution of an electric motor for the engine has been going on to a great extent in recent years, and is free from the objections which exist to the use of the transmission of steam through long pipes. The practice will probably in time oust the fitting of steam engines.

Large numbers of shears are actuated directly by an hydraulic piston. The ram or piston is enclosed in a cylinder enclosed by the head of the machine, and presses on the top slide which

carries the shear blade. The piston is of large diameter, to afford the required pressure, but a small piston in a separate cylinder is used to lift the shear blade. This is effected in an automatic manner. The two pistons are united, and the small one is always under pressure. The downward stroke of the shear is regulated by a hand lever actuating a valve which cuts off after each stroke, and whence also a branch pipe leads to the small cylinder.

Figs. 143, 144 illustrate plate shears of this type by Breuer, Schumacher, & Co. A.G. of very massive proportions. A A are two hollow standards of cast iron. Box girders B and C built up of plate and angle are united to the standards to form respectively the base, and the cross-rail of the machine. The lower shear blade block D is bolted down to B. C carries the upper sliding blade holder E, which moves in adjustable guides, and is forced down by the piston F of the hydraulic cylinder G which is fitted within the box girder. The return cylinders H H are fixed above C. The hydraulic driving gear is at J at one side of the machine. K is the operating lever. The pipe connections are clearly shown. This machine shears plates up to 60 mm. ($2\frac{3}{8}$ in.) in thickness, and 2000 mm. (6 ft. $6\frac{3}{4}$ in.) wide. Similar machines are built with steam driving gear and hydraulic return stroke cylinders.

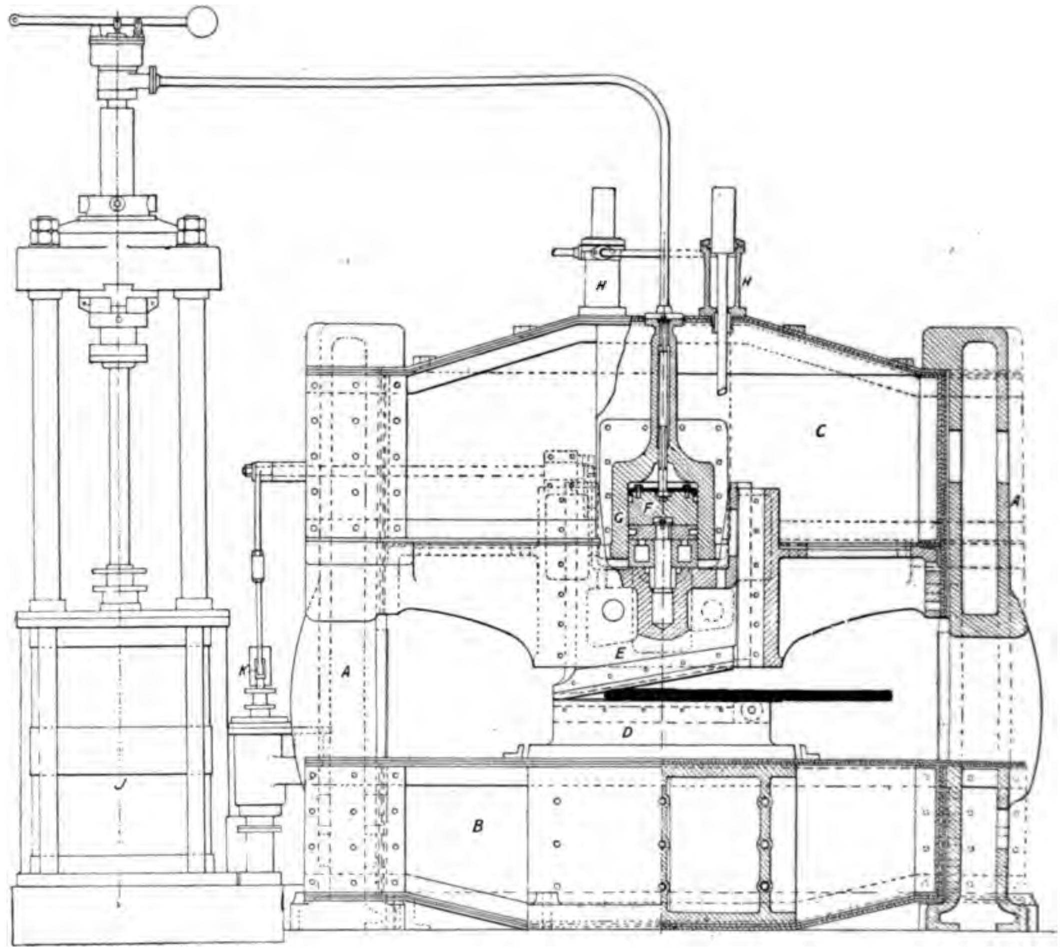


Fig. 143.—Double Standard Hydraulic Plate Shears. (Front Elevation.)

This method of a central ram is not adaptable for shears of over 5 or 6 ft. in width. The

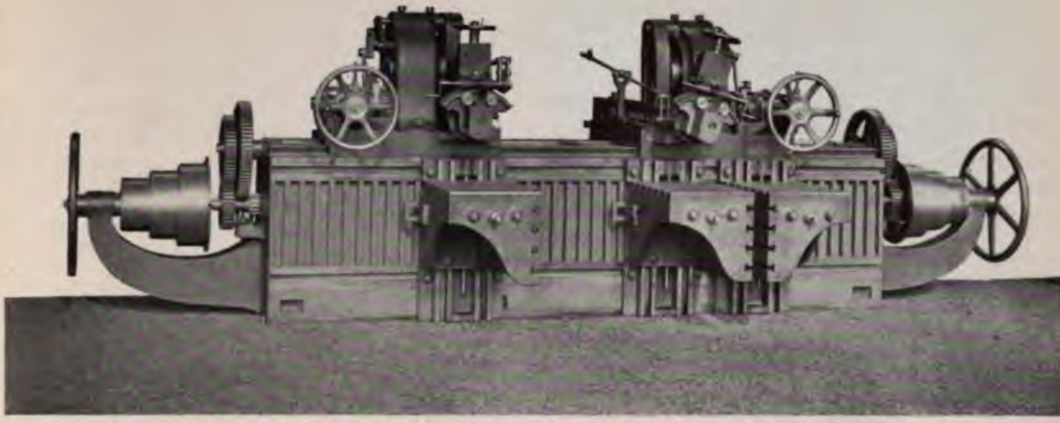


Fig. 142.—Double Headed Shaping Machine. (Thomas Shanks & Co.)

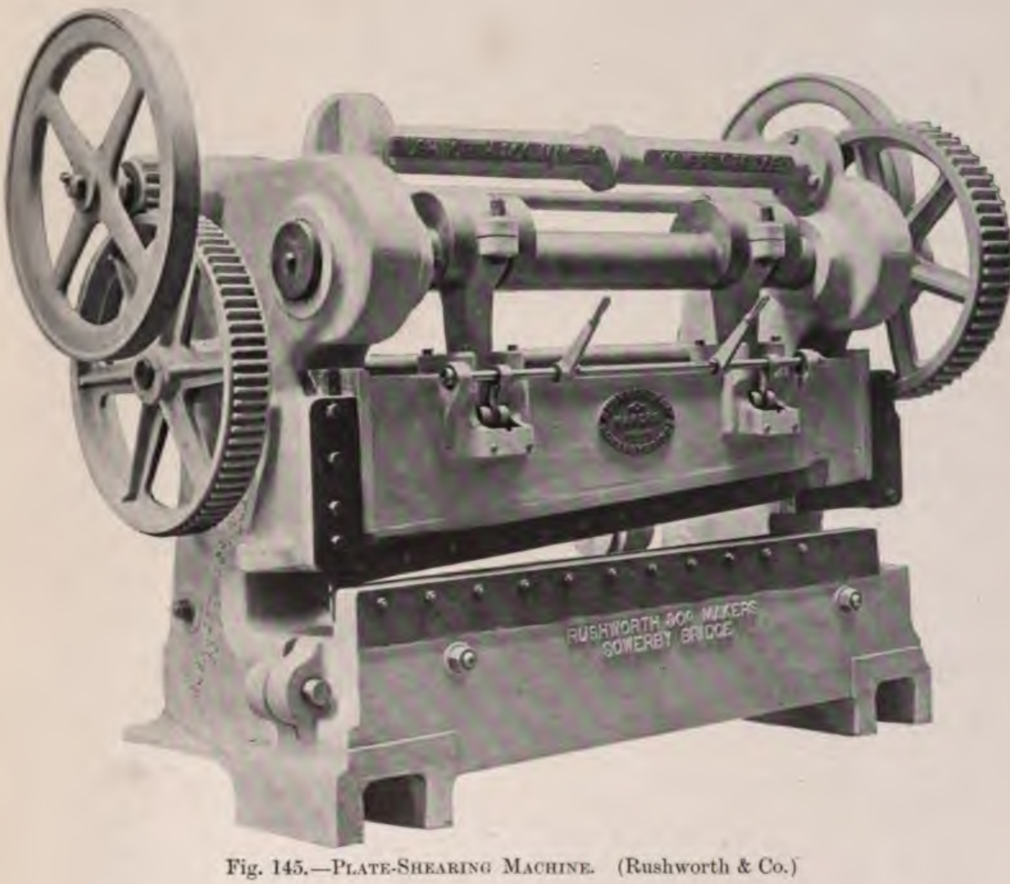


Fig. 145.—Plate-Shearing Machine. (Rushworth & Co.)

To face page 128.

large plate shears with blades ranging from say 5 ft. to 12 ft. are sometimes operated by a slide at each end driven by its eccentric, and the mass is counterbalanced by a steam or air pressure cylinder, or by weights hanging from the ends of levers. Rams are frequently used to hold the plates down securely. As in ordinary shears and punches, a stop motion is fitted to arrest the downward movement of the slide while a plate is being set. In some of the heaviest machines the top and bottom portions of the frame are united with large steel bolts which receive the stress of shearing. Double power gearing at each end, and a heavy flywheel at each end are necessary. The width between the standards governs the width of plate which can be passed through, but a plate can be sheared off at any portion of its length. Though wide shears are used when wide plates are being regularly cut, yet in the average shop narrow shears are more common, and then wide plates are sheared in detail, 12 in. or 18 in. at a time, the plate being slid along after each cut as many times as is necessary to complete the severance of the width.

A machine for shearing plates up to 6 ft. long by ½ in. thick is illustrated in Fig. 145, Plate VIII. The blade slide is moved up and down by an eccentric shaft above, operating a couple of connecting rods; these do not press directly upon the slide, but upon wedges set in pockets; the wedges may be drawn outwards simultaneously by the shaft and handles set in front, so that the blade does not descend until the attendant is ready to shear. The driving of the eccentric shaft is through double spur gears, from a belt pulley, on the shaft of which two heavy flywheels are fitted. The slide is balanced by weights and levers, to remain at the top of its stroke normally.

In another design in which the hydraulic cylinder is above the cross-rail, the pressure of the piston is transmitted to the shear slide by means of levers having arms of very unequal length. The lifting of a link connected to the longer arms of the levers thrusts down the shorter arms which are connected with links to each end of the shear slide. Two cylinders under constant pressure lift the slide after a cut.

One of these machines by Breuer, Schumacher, & Co. A.G. is shown in Figs. 146, 147. Two hollow castings A, A form the uprights. The boxed base B is built up of plate and angle stiffened at back and front with massive castings forming broad feet. The top cross-rail C is a casting to which the hydraulic cylinder D, the two return cylinders E E, and other attachments are bolted. F is the upper blade holder which moves between adjustable guides on the standards. The

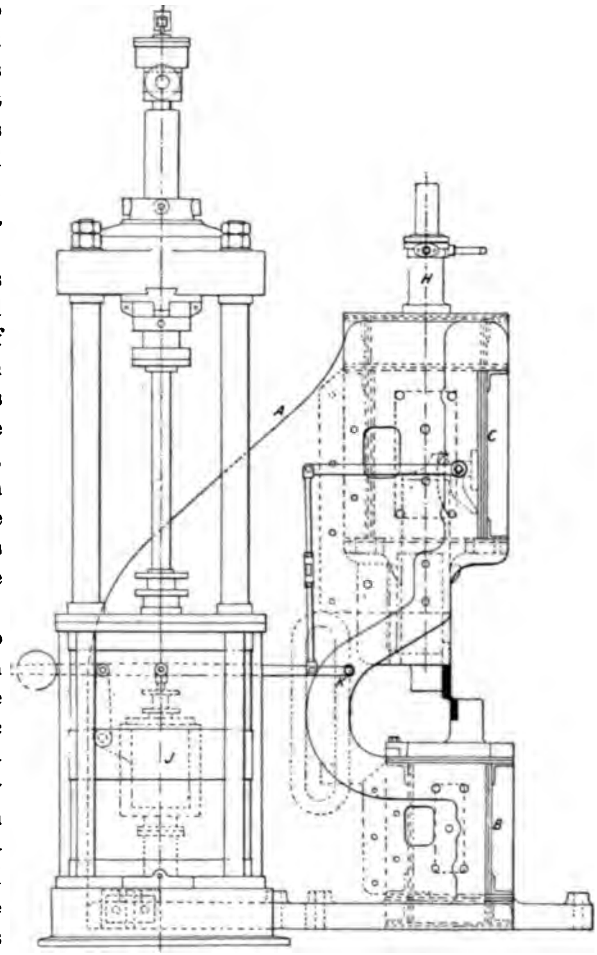


Fig. 144.—Double Standard Hydraulic Plate Shears. (End Elevation.)

method of operation of this blade holder is the principal feature of interest in the machine.

the arms of which impart a powerful thrust to F through the links K K. F is connected to the

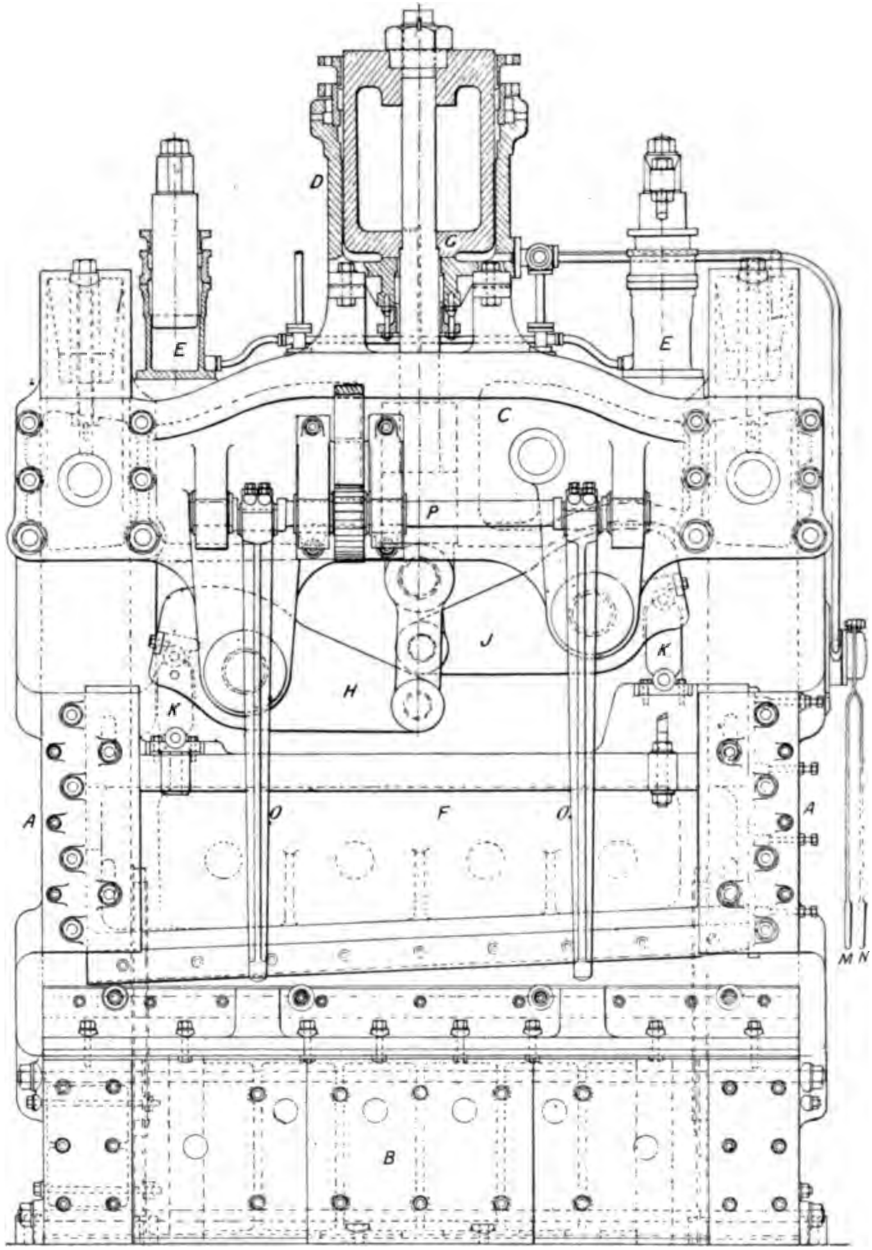


Fig. 146.—Double Standard Hydraulic Lever Shears, with Hydraulic Plate Holders. (Front Elevation.)

The pressure exerted by the hydraulic ram G is transmitted to the upper blade holder F by the two levers H and J, the relative lengths of

return cylinders E E by rods, one of which seen broken at the right of Fig. 146. Th handles M, N regulate the pressure of th

hydraulic ram. O O are plate holders which are carried on a shaft P on the cross-rail C, the plate holders being supported on eccentric pins. They are actuated by a hand lever and hydraulic cylinder having a racked piston.

There is another method of operating shears, borrowed from the action of some of the massive plate benders. An hydraulic cylinder is attached horizontally to the upper fixed portion or cross-rail of the framing, and lies between it and the movable shear slide below. The opposed edges of the framing and slide are tapered at each end, so forming wedge-shaped openings between the two, and are steel faced. The hydraulic piston is connected to rollers at each end by means of side rods, which rollers move in the wedge-shaped openings. The movement of the piston therefore in one direction pushes the slide downwards, with the advantage of roller friction. The blade is lifted by a small cylinder, or two cylinders, in the largest shears, on the top of the cross-rail. The piston or pistons being under constant pressure lift the shear blade up at a more rapid rate than that of the cutting stroke.

Figs. 148, 149 illustrate a machine of this design by Breuer, Schumacher, & Co. A.G. Here A A are two end standards which are hollow boxed castings, and which are bolted to a broad bed-plate B. C is a casting bolted also on the base B, and which carries the lower shear blade D, bolted to a holder E, having adjustment on C by means of the screws F, provided with lock-nuts. G is the cross-rail or traverse member of the machine bolted to the upper portions of the uprights A A. H is the sliding blade holder which moves in planed vee guides on the faces of A A, and carries the upper shear blade J. Both G and H have inclined faces in opposition to each other, steel faced, between which the pairs of rollers K on the two bars L are moved by the action of the hydraulic cylinder M. As these rollers are moved from left to right the long blade holder H is forced downwards powerfully by pressure at each end. N N are the return stroke cylinders which are under constant pressure, so that after each stroke they bring the rollers and upper blade holder

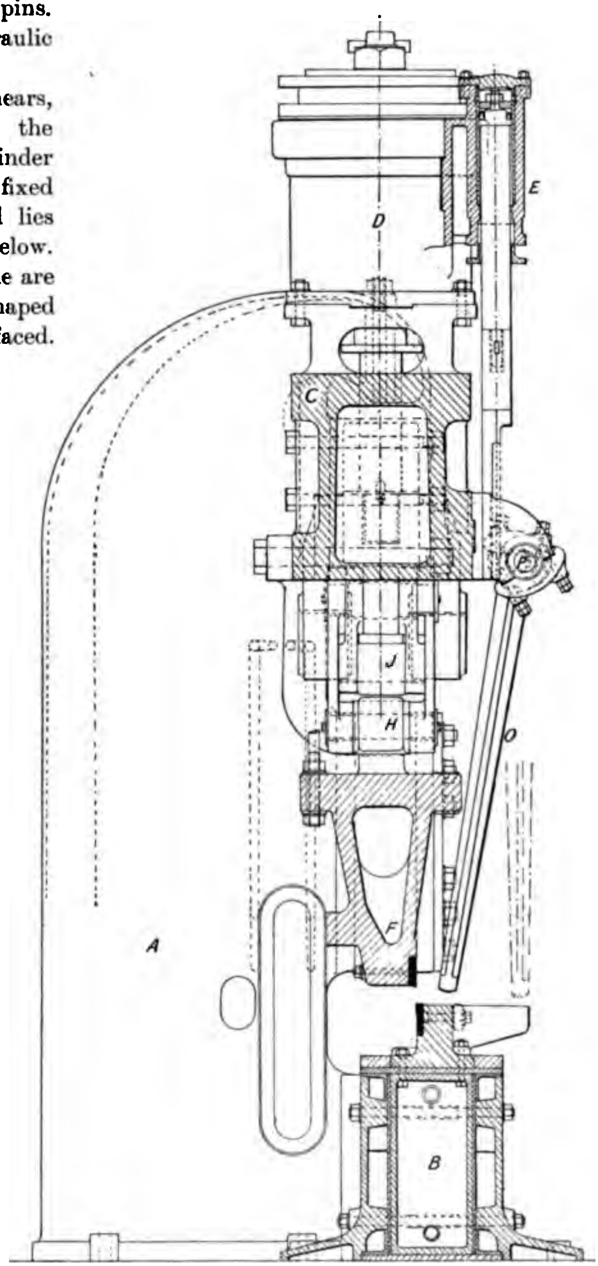


Fig. 147.—Hydraulic Lever Shears. (Side Elevation.)

back to their original position in readiness for the next stroke. The drawback movement is effected much more rapidly than the shearing

stroke. o is the lever operating the hand valve gear, and the various pipe connections are shown. The cylinders are of cast steel, the

and lengths from 1250 mm. (4 ft. 1¼ in.) to 2300 mm. (7 ft. 6½ in.).

In another design the hydraulic piston is

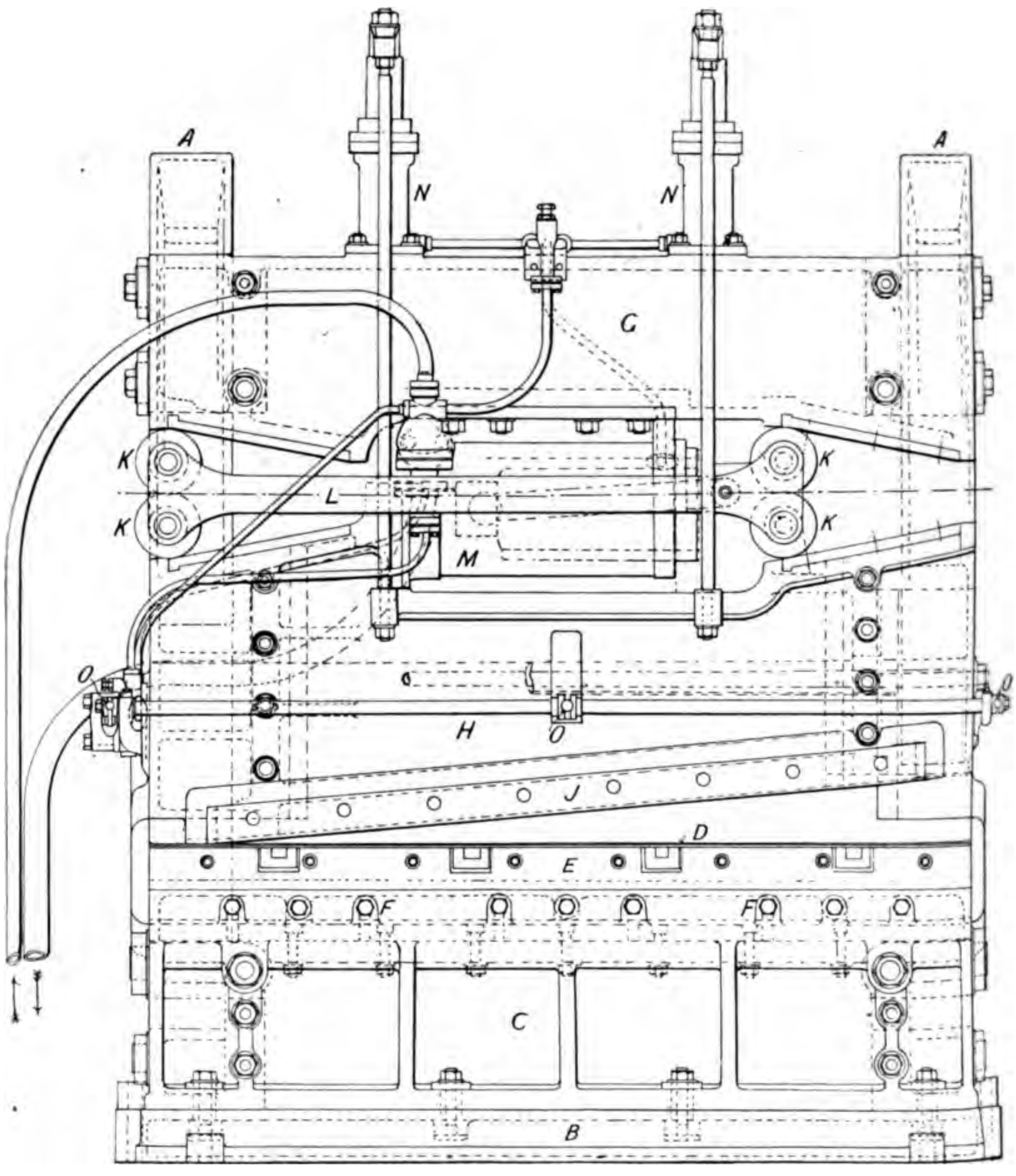


Fig. 148.—Hydraulic Plate Shears, with Wedge and Roller Gearing. (Front Elevation.)

valves, &c., of bronze. These machines are manufactured in five sizes to take plates from 5 mm. ($\frac{3}{16}$ in.) to 40 mm. ($\frac{9}{16}$ in.) in thickness,

arranged as an extension of a steam piston rod, being actuated directly by the latter. The pressure is transmitted through a pipe to a

piston above the top shear. The shear is lifted by a small steam cylinder under constant pressure.

The framings in these machines are of a composite character. The base and the cross-rail are box girders, the standards of cast iron. The deep webs of the girders are stiffened with blocks of cast iron bolted down the sides.

Built-up framings of steel plate and angles are also used exclusively in the machines of Henry Pels & Co. In the illustrations, Figs. 150, 151, the excellent disposition of material is noticeable, while the weight is far less than in machines with cast-iron framings.

Numerous forms of shearing machines are made for special purposes, as for bars, blooms, billets, sheets, strips, angles and tees, joists and channels, each of which entails modifications in dimensions, and in some cases in shapes of the shear blades.

Pels' machine for rolled steel sections severs these more rapidly than cold sawing does. Though the ends are not so smooth as when sawn, they are sufficiently accurate for much bridge and girder work. One of these is shown in Fig. 150.

A horizontal shaft which may be belt or motor driven (belt in this case) has a massive flywheel A to equalise the speed. This shaft through a connecting rod, B, imparts an oscillating movement to a lever at one side. A pawl on the inside of the lever drives a ratchet wheel at the fulcrum end of the lever, and which drives a shaft in a step by step motion to which it is attached. An eccentric on this shaft works inside a massive forging, C, which projects to the front of the machine and carries the cutting tool D. A large ratchet wheel attached to the eccentric shaft, and a pawl on the framing prevent the shaft from returning on the return stroke of the driving ratchet.

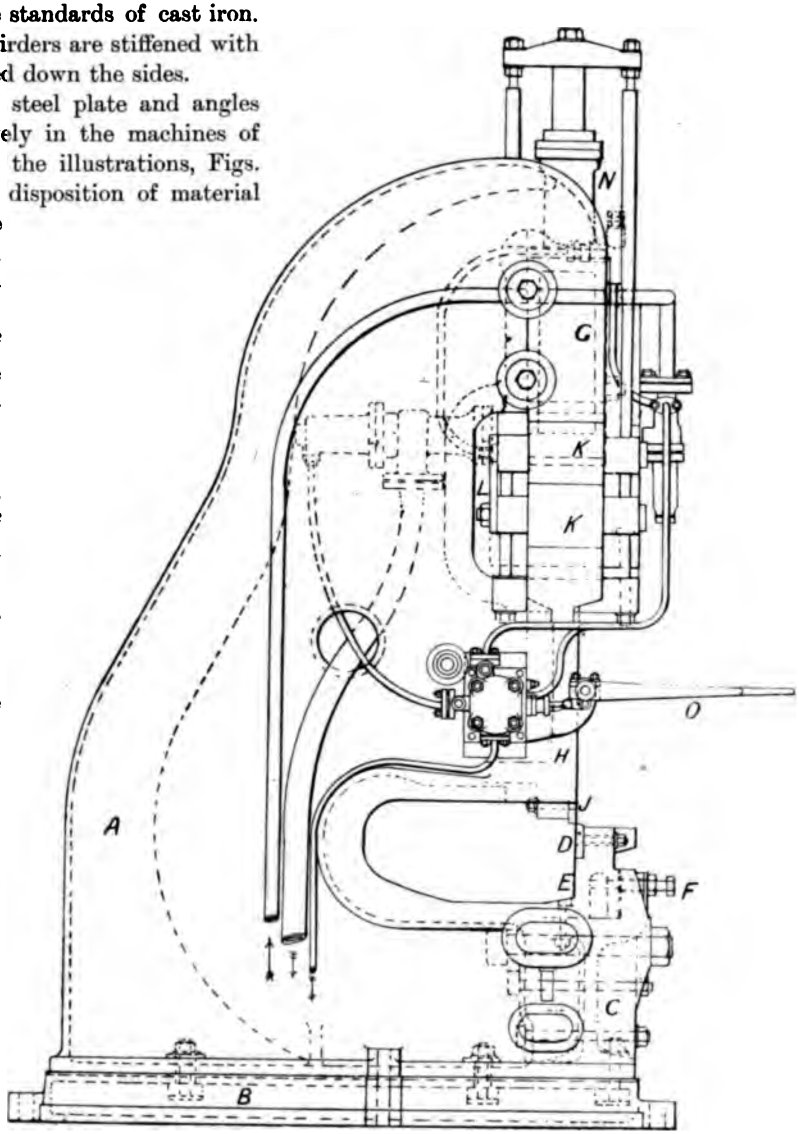


Fig. 149.—Plate Shears. (End Elevation.)

The tool D used for shearing is a plate of about $1\frac{1}{4}$ in. thick, of rudely triangular form truncated at the lower face. Its action is rather peculiar,

not being directly detrusive but compounded of horizontal sliding and vertical motions. The cutting takes place in an inward direction.

A joist is cut across half its width, and then turned over for the other half to be severed. The ratchet mechanism is put into operation by pulling the lever E down; it goes back on release, by the action of a spiral spring. The joist lies on an anvil or bed F between the halves of which the blade D passes. There is a bar, G, adjusted for height by means of a ratchet and catch, which keeps the joist in place while being shorn. The counterweight H, acting through a rope and chain, pulls the cutter upwards after the cut. It will be noticed that the frame of the machine is built up of steel plates, angles, &c., riveted and bolted together. This is a special feature of Messrs Pels' machines; it makes them lighter than cast iron, and not so liable to fracture. Notching machines are constructed somewhat after the style of the joist shears, but with special cutters, and anvils to suit the requirements of notching pieces out of the ends and sides of joists, channels, &c.

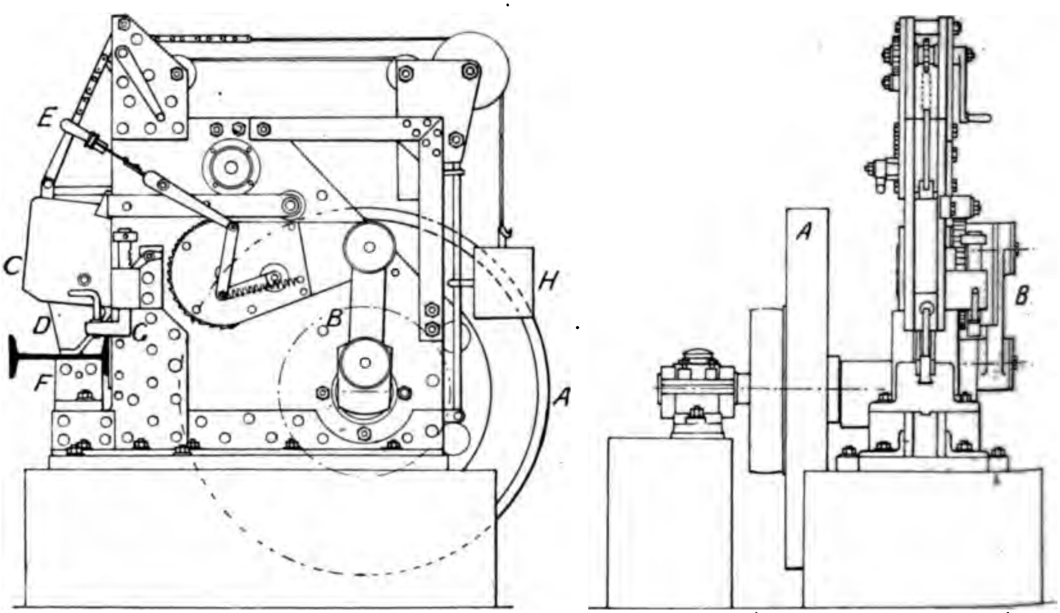


Fig. 150.—Joist Shear.

Another handy machine is the bar, angle, and tee bevel cropper, Fig. 151. Here the frame, also of steel plating, carries a driving shaft with pulley A, and flywheel, actuating the connecting rod B and the ratchet lever C. This works two slides D and E, the one to the right for tees and bars, the other to the left for angles and bars. The blades for tees and angles are screwed on at the bottom, and sever the sections as they rest on supports; the screw dogs F are adjusted to prevent the work from tipping. Bars, of round, square or other profiles are cut by sliding blades at G and H; these blades have holes cut through them corresponding to the sections, and they slide in close contact past plates in front, also with appropriate apertures, so that the bar is shorn off neatly without bending or distortion. The cutters and guides may, of course, be changed to suit any other sections that are wanted.

A type of bar, angle, and tee cropper is shown in Fig. 152, Plate IX., differing from Fig. 151 in shape, but having blades worked in a similar manner. The machine is belt-driven, takes about 12 HP. and makes fifteen strokes per minute. The following sizes of sections can be cut, all without changing blades:—Rounds up to $3\frac{3}{4}$ in. Squares to $3\frac{3}{8}$ in. Flats to $6\frac{1}{4}$ in. by $2\frac{1}{8}$ in., and 10 in. by $1\frac{1}{4}$ in. Angles to 8 in. by 8 in. by 1 in. Tees to 8 in. by 8 in. by 1 in.

ig. 152.—Bar, Angle, and Tee Cropping Machine.

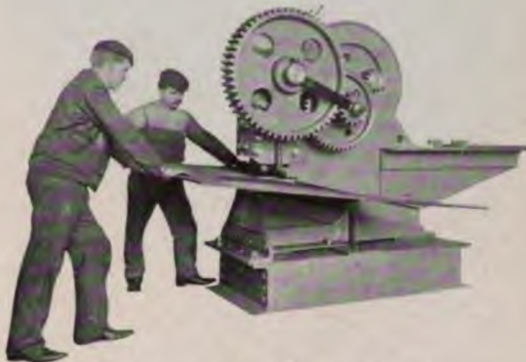


Fig. 153.—Plate-Shearing Machine.

(Henry Pels & Co.)

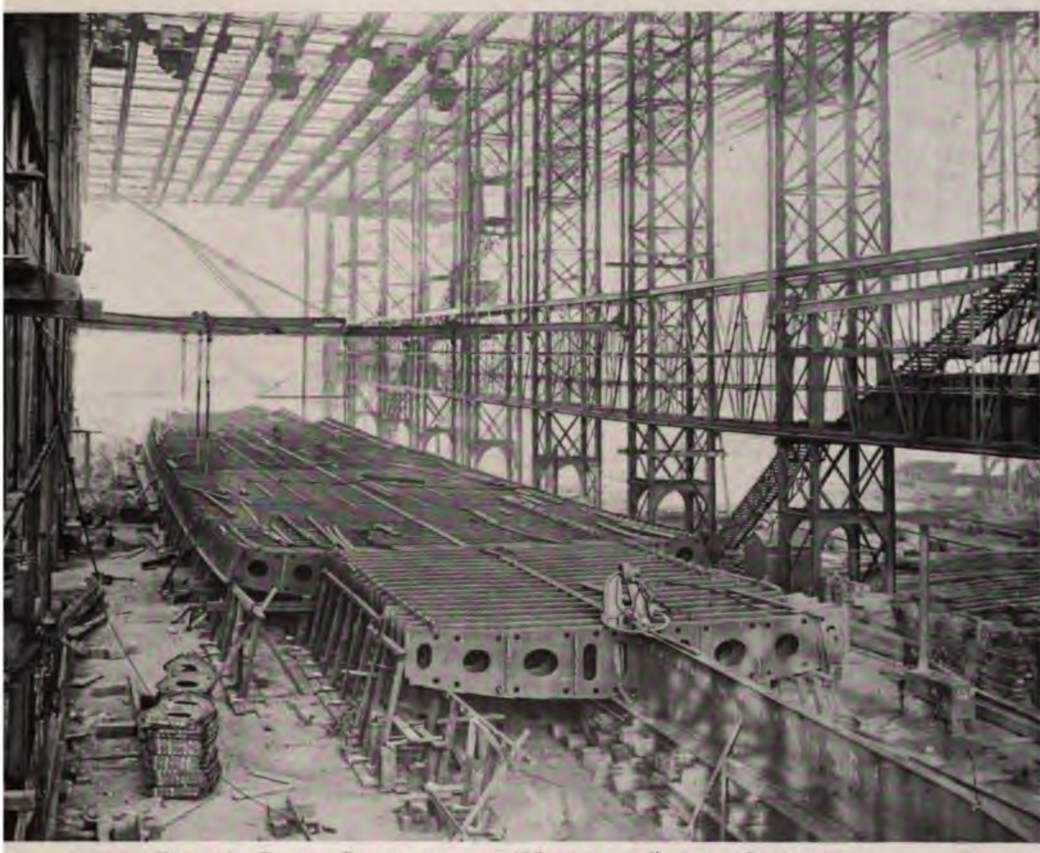


Fig. 166.—Double Bottom of the "Mauretania" under Construction.
(Swan, Hunter, & Wigham Richardson, Ltd.)

To face page 134.

The splitting shear, Fig. 153, Plate IX., cuts plates of unlimited length and width, up to $\frac{7}{8}$ in. thick, the sides of the steel frame being cut away to allow the plate to be fed forward as it is severed. The shear blade is moved up and down by a double spur gear drive, actuated by a belt pulley; there is an extension at the rear to receive an electric motor, which can be then belted to the pulley, rendering the machine self-contained. The toothed wheels seen are, of course, covered with guards when the machine is in use. The shear blade makes twenty strokes per minute.

The alligator or crocodile shears is a special form, differing from others in the hinging of the upper shear blade in scissor-like fashion. The lever on the other side of the fulcrum is oscillated by a connecting rod variously driven. The machine is used in the iron and steel works for cutting up scrap, puddled bars, and similar light duty. These may be attached to the large plate shears when used for cutting up the shearings. Or they may be independent. In the latter case they are driven by belt pulleys, the usual flywheel being fitted, and the driving is through a pinion and wheel. A cam on the shaft of the latter actuates the top shear. Machines of this kind are made to shear up to $\frac{3}{4}$ in. thickness.

Rotary Shears.—Plates or sheets not exceeding about $\frac{1}{4}$ in. thickness can be cut on the rotary shears, which are largely employed for sheet-metal working. Two revolving blades, driven by hand or by power, are set with their bevelled edges just in contact, so that if a sheet is fed past them, it will be severed. A machine, by Taylor & Challen, Ltd., for cutting sheets up to $\frac{3}{16}$ in. is shown in Fig. 154. The frame carries the two cutter spindles A, B, at the ends of which the cutters C, D, $4\frac{1}{2}$ in. diameter by $\frac{3}{4}$ in. thick are bolted. Sliding bearings receive the spindle journals, so that adjustments may be effected by means of screws to suit different diameters of cutters, and this necessitates a special mode of driving, from the pulleys E, fast and loose. The lower spindle B

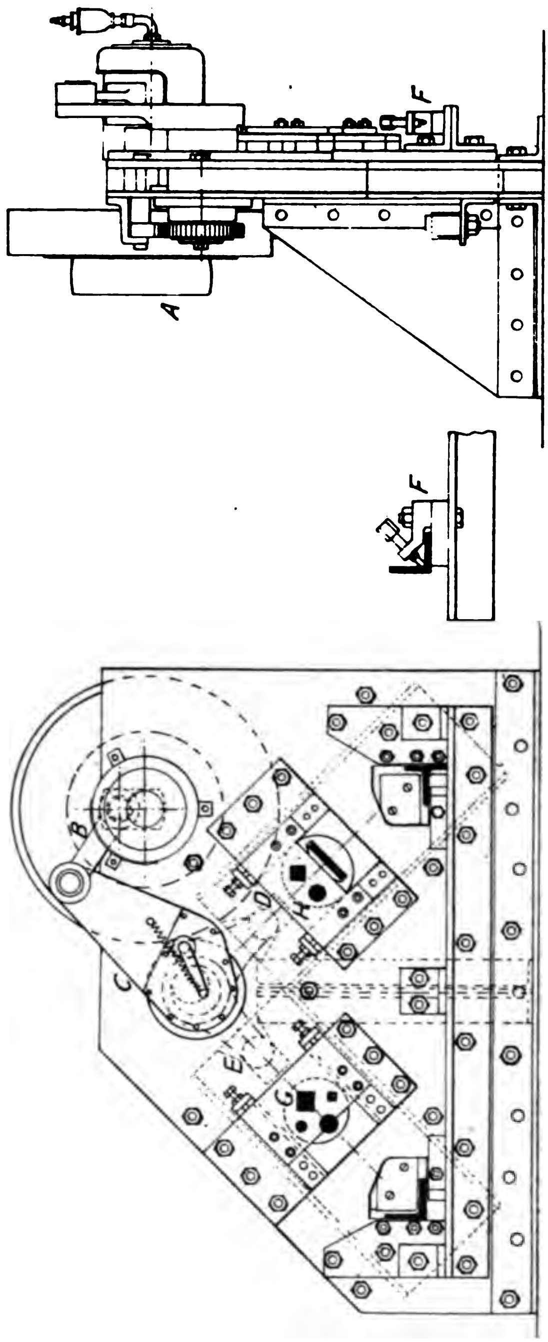


Fig. 151.—Bar, Angle, and Tee Bevel Cropper.

is driven direct from the fast pulley, but a train of spur gears (seen in the end view) conveys the

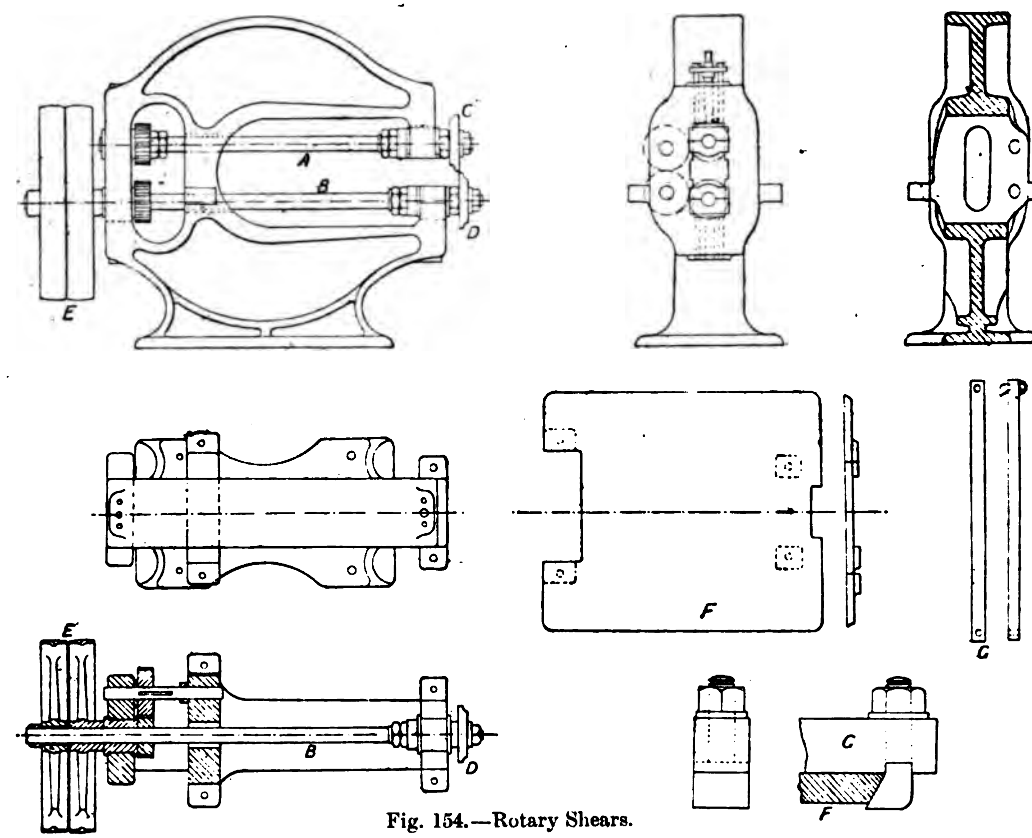


Fig. 154.—Rotary Shears.

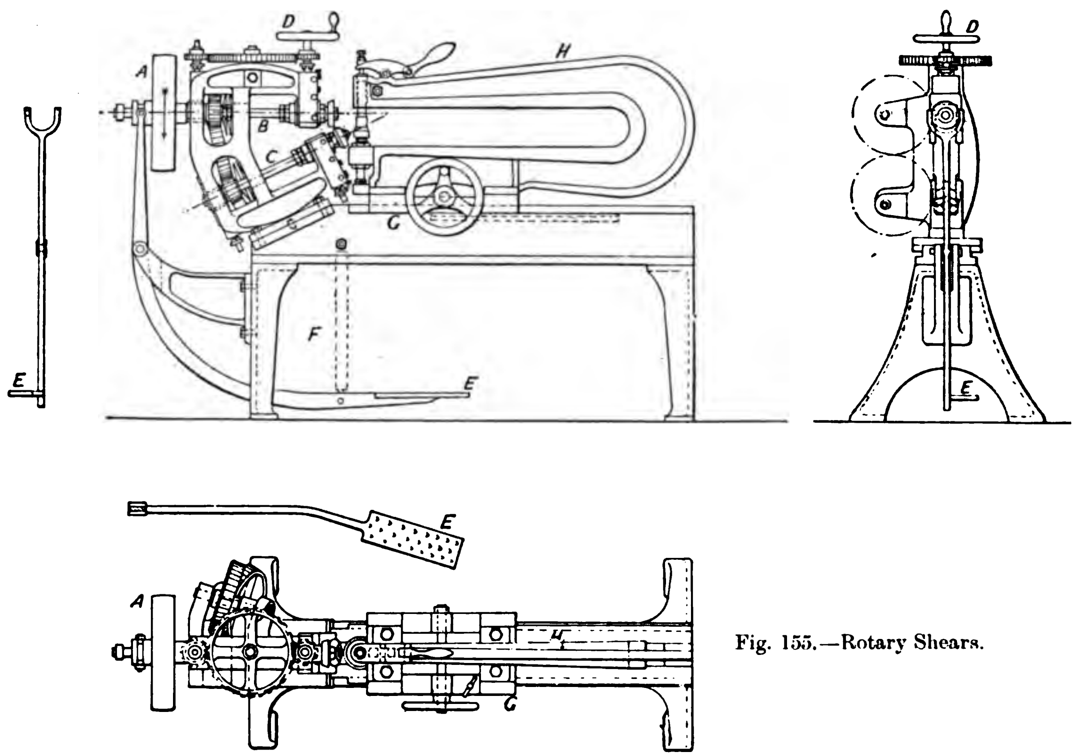


Fig. 155.—Rotary Shears.

motion to the upper spindle, so that some little vertical latitude is afforded without interfering with the meshing of the gears. The table F is bolted to the four lugs provided, and sheets are slid across it, guided by the gauge strip G, which is held down to the table by hooked bolts, gripping the bevelled under edge.

The rotary cutters are also used for cutting circles, the sheet being twirled upon a centre pivot set at the required radius. Tinplate works employ them largely, for cutting out blanks for stamping. Messrs Taylor & Challen's type (also termed circle or ring shears) is shown in Fig. 155. The pulley A drives the two spindles B and C through crown bevel wheels which allow of adjustment for centres, the adjustment being effected by screws sliding the bearings; the top ones are moved simultaneously by the spur gears and the hand-wheel D. A clutch connected to the pulley A stops or starts the machine, on operating the treadle E; the spring F puts the clutch out of gear when the foot is taken off. The slide G is adjustable along the bed by hand-wheel and rack and pinion, and it supports a bow H, giving clearance for circles of large diameter. The plate is held between the two spindles, above and below, the upper one being forced down tightly by a lever and cam handle. The enlarged details, Fig. 156, show the construction clearly. The lower spindle J runs in a split bearing, adjusted as wear occurs, and in another below, with a ball thrust. The anvil K supports the plate, and the plunger L of the spindle M is forced down; a ring of balls eases the friction of M against the thrust stud N. The details of the cutters, with their bearings, slides, and adjusting screws will be evident; the

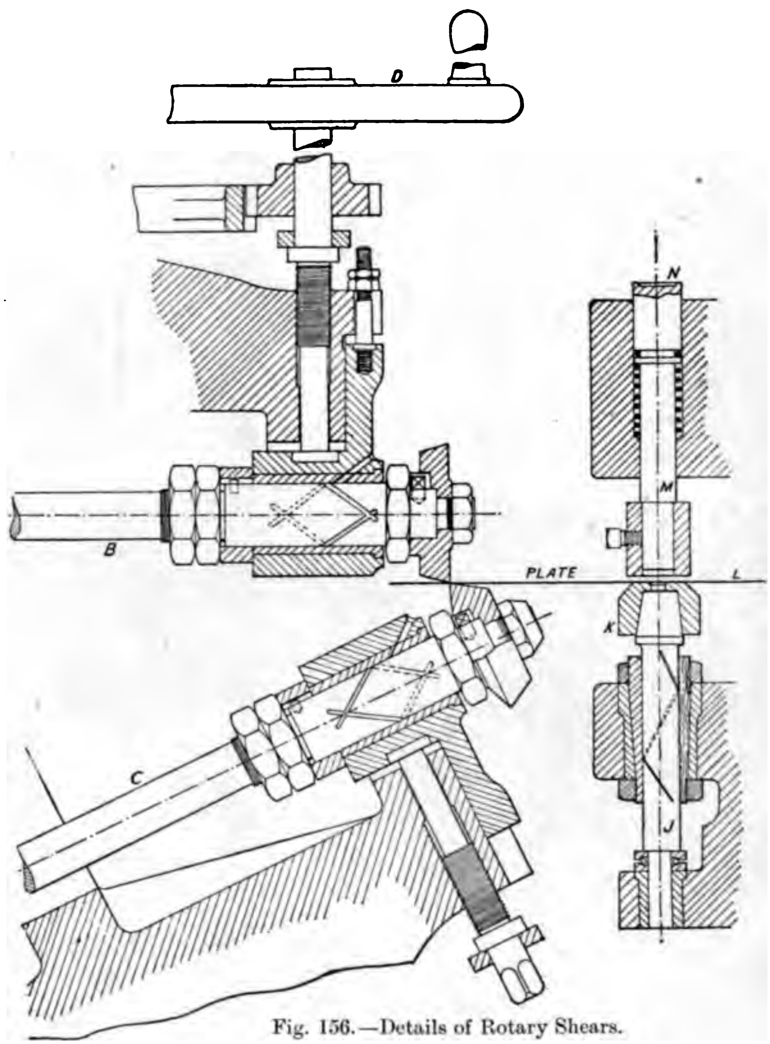


Fig. 156.—Details of Rotary Shears.

cutters are $3\frac{1}{4}$ in. diameter. The size of circle which will be sheared is determined beforehand by observing graduations on the bed, when moving the slide G, Fig. 155.

Shearing Tools.—The type is the common scissors. At the other extreme are the shear blades used in shearing machines. Two blades

are essential to any shears. A punch may be considered as a circular shear blade. In all, the action is partly detrusive, partly cutting. In the scissors the cutting predominates, in the shear blade the detrusive action, the angle of the cutting edges being from 80° to 85°. The edge left by a shear blade is rough, as though the metal were torn away. It is a matter of indifference whether one blade is fixed, or both are movable.

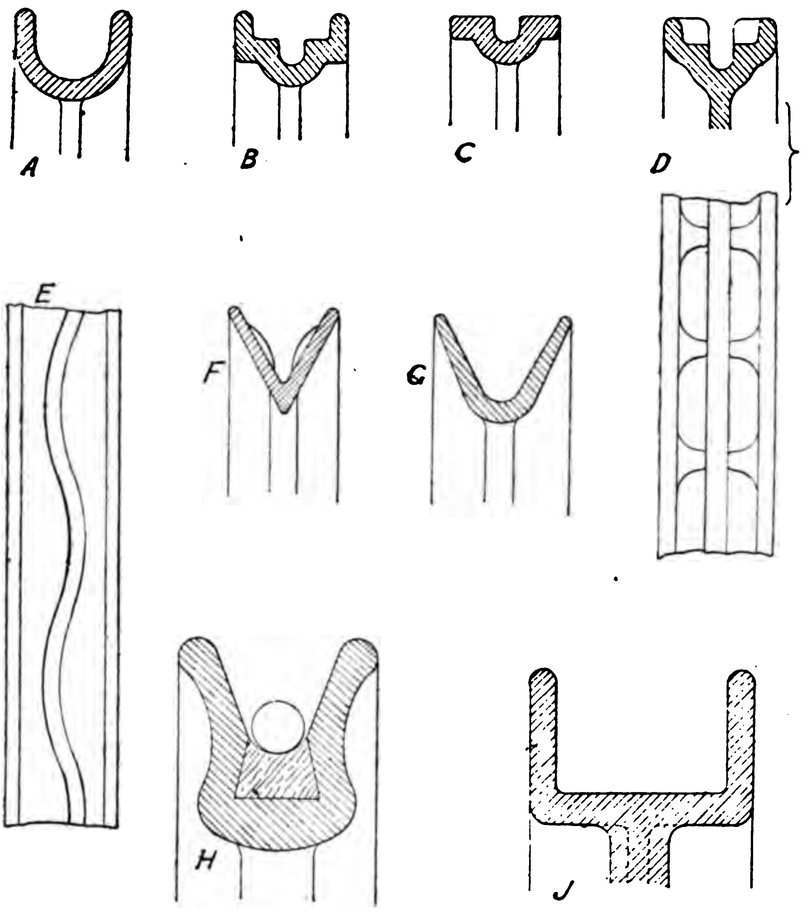


Fig. 157.—Pulley Grooves.

Shear Steel.—Bars of blister steel are separated after conversion into grades, and either rolled or drawn out under the hammer into bars, *bar steel*. These are cut up, piled, and welded, for the production of shear steel. The pile is termed a *fagot*, and oxidation during heating is prevented by covering it with fire-clay and borax, and heating in a hollow fire. When welded and drawn out the product is *single* shear steel. If a more homogeneous quality is required the bar is cut, doubled on itself, reheated, rewelded, and rehardened, and is then termed *double* shear steel.

Steel intended for these qualities must contain more carbon than that intended for casting, because the effect of fagoting, reheating, and welding, notwithstanding the precautions taken, is to partially decarbonise the steel. The *shear heat* or *temper* represents a longer period of carbonisation than the first or *spring* temper does, and the *double shear heat* a still longer one. It has a more uniform texture than the crude blister steel, and is suitable for cutlery, mandrels, and spindles.

Sheave.—The body of an eccentric, as distinguished from its encircling strap. Also a sheave pulley.

Sheave Pulley, Wheel, or Sheave simply. — A pulley grooved to receive chain or rope. The latter have been dealt with under **Rope Driving**, and **Ropes**. The present article relates to those used for chains.

Sheave pulleys for chains are made in several different types shown in Fig. 157. The first, A, is of a plain curve in which the links lie diagonally. The two objections to this are that the chain is very liable to become twisted, which is an evil to be avoided, and that the flanges are apt to become fractured by the surging of the chain, or of accidental running

up to the hook. It is more suitable for a guide chain than for hoisting tackle.

Fig. 157, B, is the most common type, and it has the advantage of preventing the chain from twisting, the alternate links lying flatwise and edgewise. The only objection to it is the risk of the flanges becoming broken by the surging of the chain and hook. They will also fracture if the chain links make a tight fit edgeways. But with due care in working, and by making the flanges moderately thick, they can be relied on. In cranes doing heavy work, in stone quarries particularly, the shape shown in C is often adopted, and it is as good as the previous design when the chain is of no great length. The other type has, however, an advantage over it in the fact that the chain is not liable to get out of the groove in consequence of surging.

The type in Fig. 157, D, in which each link lies in its recess, is in many classes of work preferable to the others. It is so when the pulleys have to be of small size, because small smooth grooved pulleys distress the chains severely. The recesses are essential when a chain is used as a transmitter of motion, as in derricking jibs, and racking. The disadvantage is that links will elongate in time due to the strains incidental to wear, and then they may override the recesses. The evil may be minimised by making the recesses longer than the links, but even then overriding will develop if the pulleys are of large diameter, receiving a considerable number of links. In small pulleys no such trouble need occur. Common chain, pitch chain, and wire rope are used for racking jennys along gantries. The first is cheap, the second expensive but reliable, the third is probably the best.

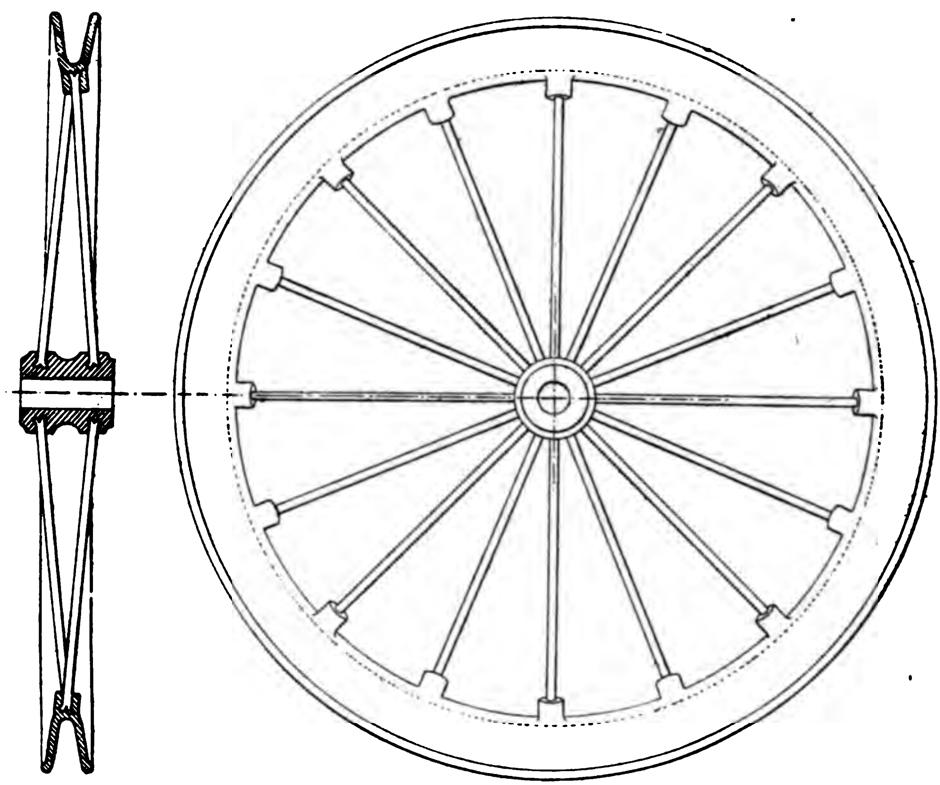


Fig. 158.—Large Sheave Pulley, with Wrought-Iron Arms.

The minimum diameter of a plain sheave

should not be less than thirty times the diameter of the bar from which the links are made. But if the sheave is recessed to receive each individual link, then there is no limit to the reduction which may be made in its size,

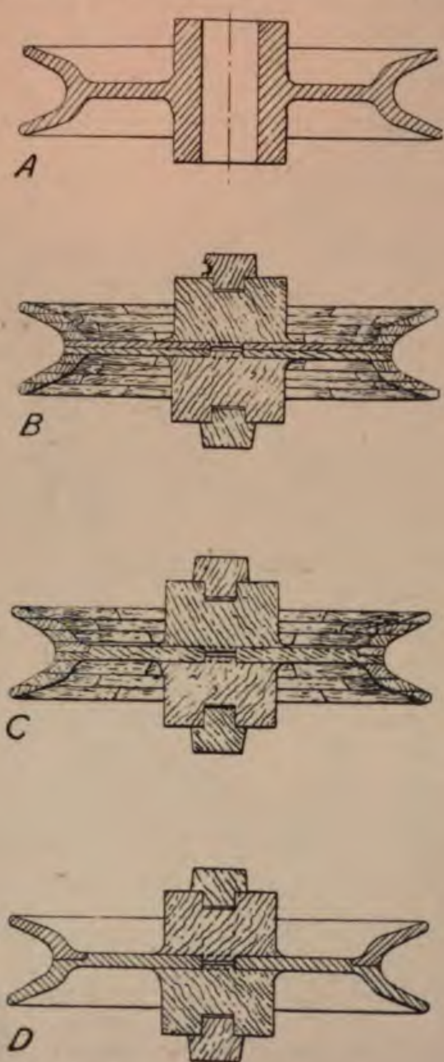


Fig. 159.—Pulley Patterns.

because each link has a flat bedding and is subject to no bending action.

Another form of sheave is the *waved wheel*, E. In this the groove of the rim takes a sinuous course laterally, not at the periphery, but on the sides and bottom, so giving an excellent bite on chain or rope.

There is another form of sheave used for ropes and small chains. The groove is approximately vee'd in section, F, and nibs are cast at intervals to aid the bite of the chain. These vee'd sheave wheels used for the ropes and chains on overhead travellers worked from below are made of cast iron, usually with wrought-iron arms cast into the rim, and into the boss. They are always very spider-like in character, as the work imposed upon them is very slight, and it is desirable never to unduly increase the dead load of a crab. Wheels for ropes have smooth vees, but those for chains must have the small nibs mentioned cast at short intervals. The friction of the rope will hold in a smooth vee, but a chain would slip without nibs to bite the links. The bite of a rope is also increased by the use of guide pulleys, which increase the arc of contact of the rope. G shows the section of a wire rope pulley, and H one fitted with a wooden bedding for the wire, to avoid chafing and wearing it unduly.

Flat wire rope requires a flat bottomed sheave, J, which is smooth, the bite of the broad rope with its arc of contact ensuring enough hold. Round ropes are also used in these.

Manufacture.—Sheave wheels are made from patterns, and cast in iron, steel, or bronze. Being usually required in considerable numbers they are mostly made from full patterns, but large wheels are more often moulded in cores. The centres are solid plated, or have arms. The arms are cast, or are of wrought iron, Fig. 158. This latter practice is usual in large wheels for pit heads, and overhead hand travellers. The shrinkage strains and risks of large cast-iron arms are thus avoided. Built-up wheels are unusual.

The small pulley patterns are usually divided through the centre. Fig. 159, A, shows a casting, and B its pattern, the halves being either checked or dowelled together. The half thicknesses of the central plated portions are made with open joints, and the rims built on these in segments. Only in the large patterns is it usual to build the centre up with segments. Sometimes the centre is built up, or made solidly, with open joints, and the top portion of the rim checked into it, Fig. 159, C. The objection to this is

loose rim lacks support, and is liable e damage. The bosses are fitted loosely ıds, to permit of changing them, and ifferent sizes on the same pattern rim. a metal pattern, with wooden bosses, ngeable.

a sheave pattern is fitted with arms, 0, the latter are also ıade in halves, or in an thickness, with corres- differences in the fitting m. The arms are locked at the centre, similarly arms of toothed wheels. weak about the centre, fitting of the boss and ical arms stiffens them. onsiderable numbers are off these patterns they erally made in metal, on, or brass.

wrought-iron arms are the rim, with its bosses, central boss have rather ints fitted of the same r as the arms. Usually are strutted to impart rigidity as in 3. The bosses and prints must then he disposition of the arms. A small attern would have its prints continuous ss to rim, so connecting the two, but ıes have the two members distinct nts of say about 3 in. long only. Then ılder centres and sets the boss mould urement.

a rim is made in cores, two boxes are for the internal and external portions vely, and the cores are deepened at the the rim to form a joint there. They on a level sand bed to a circle struck Made in this way, wrought-iron arms l. Fig. 161 shows a section through h cores and a wrought-iron arm. A ıter core which forms the recess. B the re which forms the outside of the rim arm bosses. Rods will be noticed which the sand, and the mass of ashes in the f A which receives the vents.

rn rims are turned to their sectional the aid of templets working from the joint faces, and the back of plate or arms. When recesses are made for links to drop into, these are cut with gouge and chisel, and an actual link is fitted in them. Much care has to be exercised in pitching round, and clearance must be given. A length of several feet of chain should be taken, and the pitch of links averaged, as single links vary in length. A chain stretches with use, so that if fitted when new it does not fit afterwards. It is, therefore, well to make a little allowance for stretch in pitching round.

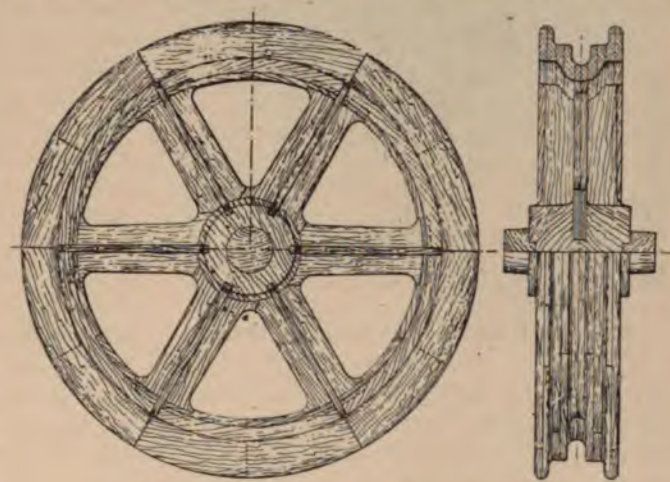


Fig. 160.—Pulley Pattern, with Arms.

All sheaves require two mould joints and a middle, Fig. 162, with the exception of those which are cored in the rims. It does not follow that a middle part box is necessary, since a sloping joint is often made, and the middle sand lifted away on a ring if small, or on a grid if large. Large moulds have a middle part

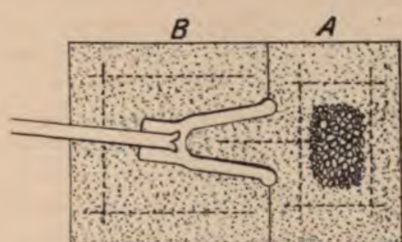


Fig. 161.—Section through Rim Cores.

box. The sand which projects within the rim is supported with nails or small rods laid in radially.

There is not much advantage in building up rims solidly and coring out the space as in Fig. 163. The only advantage is that of greater rigidity than recessed rims possess. Against this must be set the extra cost of cores. Cores are useful when the object is to save the expense of a full pattern, but they are not economical for standard work to be continually repeated.

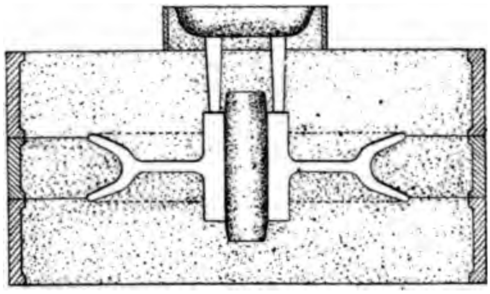


Fig. 162.—Section through Mould of Sheave.

When wrought-iron arms are cast in rim and boss, their ends are hatched over by the smith to assist their retention by the metal. They are warmed before insertion, and coated with coal tar, or blackening, or oil. The ends are cast in the rims first, and after the rim has finished shrinking the boss is cast round the other ends. If this precaution were not taken the rim would become distorted or break.

For the best work the rims of plain sheaves are turned smoothly to lessen the wear of the chain.

Sheer Legs.—A type of hoisting machine developed from the tripod arrangements of timbers erected for temporary service out of doors. Three legs are secured at the tops by a bolt passing through the three, and being spread at the bottom, they are prevented from slipping by spikes in the ends pushed into the ground. A set of pulley blocks is suspended from the apex for hoisting and lowering the load.

Permanent sheer legs are used in running sheds and repairing shops for hoisting locomotives or wagons by one end for the examination of axle boxes, of axles and wheels, and repairs or renewals, as well as for similar purposes, in cases where the work can be run underneath the legs. There are two forms of these. In one the legs are spaced about equidistantly, and a crab is located at a little distance away for the work of hoisting; the chain or rope passing thence over pulley blocks suspended from the apex for heavy loads, or over a plain pulley for light lifts. In the other, two of the legs are brought sufficiently close to one another to receive the hoisting gear carried in cheeks bolted to the legs. In this design the legs do not meet in an apex, but the two adjacent legs are connected to the single leg by a horizontal beam, whence the tackle is suspended.

In these the legs are made of timber or of rolled steel sections. If in timber, shoes are cast to receive the ends. In steel, feet are riveted on with angles. The lower ends are sunk 2 or 3 feet into the ground. Loads of from 1 to 15 tons are lifted by sheers of these types.

Masting Sheers.—These are very powerful, designed specially for lifting masts, boilers, engines, and machinery into vessels after launching. The two front legs are hinged, and reach over the vessel, being adjustable for radius by a single hinder leg or rigid guy which is moved outwards or inwards by a large square-threaded screw turned by steam engines, hydraulic rams, or electric motor. All the power mechanism and gear is carried on framing enclosed under the cover of a shed or house. In steam-driven sheers, the crab fitted with link reversing gear actuates a lifting drum for the load. In large legs there are two drums, one for maximum loads at slow lifts, another for light loads at rapid lifts. Drums are pro-

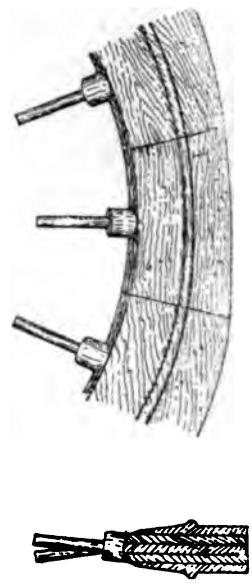


Fig. 163.—Solid Pattern Rim.

vided for coiling the guy ropes for regulating the radius of the masts.

The great objection to sheer legs in shipyards is the want of slewing capacity, and the narrow limits of radial reach. To some extent, therefore, their place has been usurped by derrick cranes. But in recent years the giant, or shipyard cranes have largely displaced both. In these the tall mast, the long cantilever arm, and the travelling jenny, are vastly more handy and mobile than either the sheer legs, or derricks. *See* **Shipyard Cranes**.

Figs. 164 and 165 illustrate a set of 100 tons masting sheers by Messrs Cowans, Sheldon, & Co., Ltd. They are representative of the general type in which these sheers are built by this firm for various purposes, up to 150 tons, and actuated by steam as in the example, or by hydraulic, or electric power. The following are the principal elements of the sheers.

The sheers or front legs A, A are pivoted at *a*, *a*, and are connected at their upper ends to the back leg or guy B. The lower end of the guy is traversed horizontally by a horizontal screw working in a gun-metal nut. The centre of the screw is at *b*, and the range of nut is given on the drawing, 62 ft. 10 in. The weight of the screw is supported by tumblers at *c*, *c*, *c*.

The three legs are built similarly of steel plates, bent into a tubular form, turned on the ends, butted closely and riveted with circular butt straps. The holes for the rivets are drilled. This, with the cambered form combines lightness of structure with great strength.

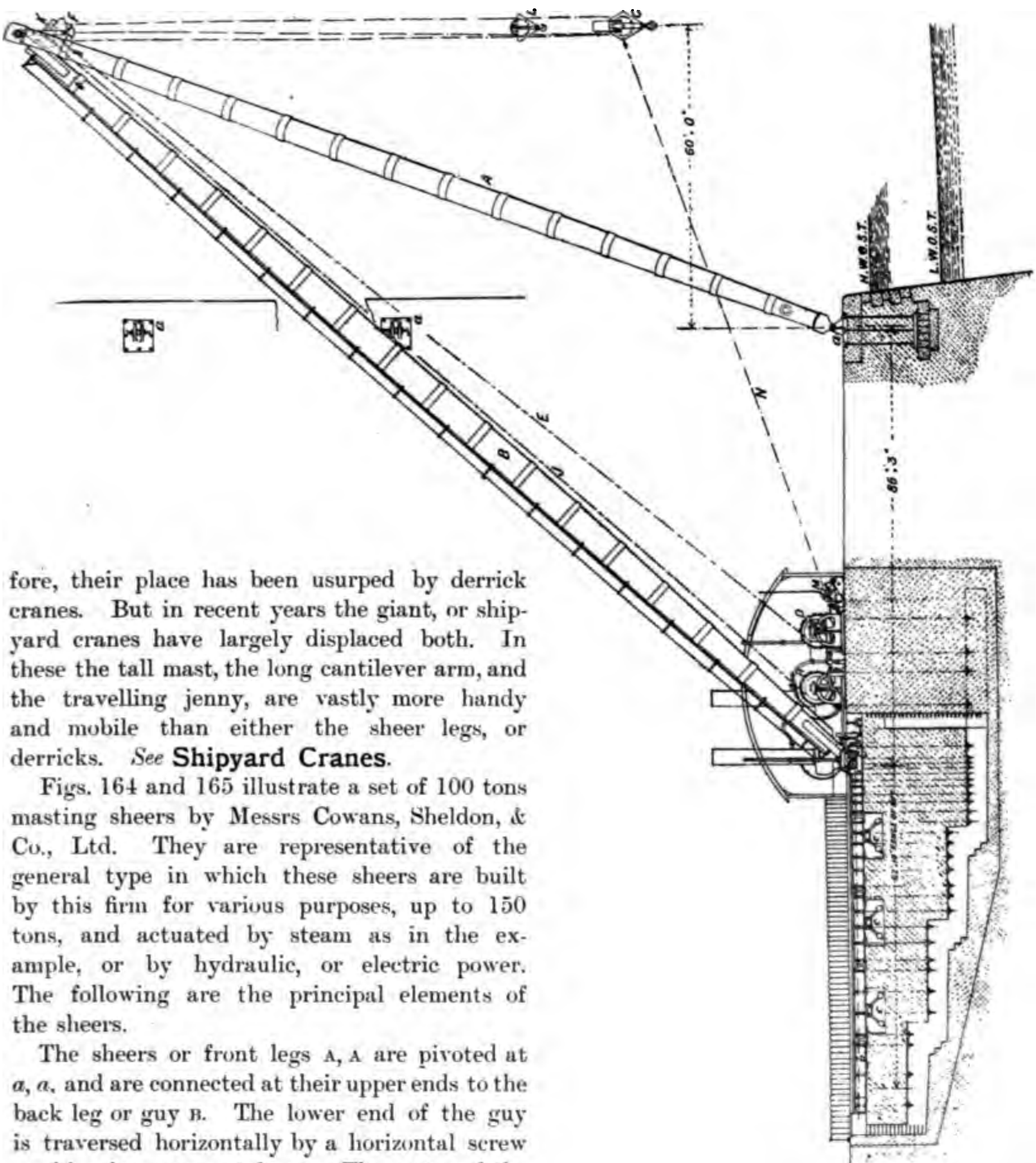


Fig. 164.—100-Tons Masting Sheers.

The back leg has a ladder fitted, by which a man gets up to oil the top pin and shackles. The power for the horizontal adjustments of the legs is provided by the pair of engines

indicated in end view at C. Separate engines are used for hoisting, but the scale is too small to show them.

The main or heavy hoisting is done with a pair of drums located at D. On these are wound two steel wire ropes E, 5½ in. in circumference, and 1,090 ft. long, which pass

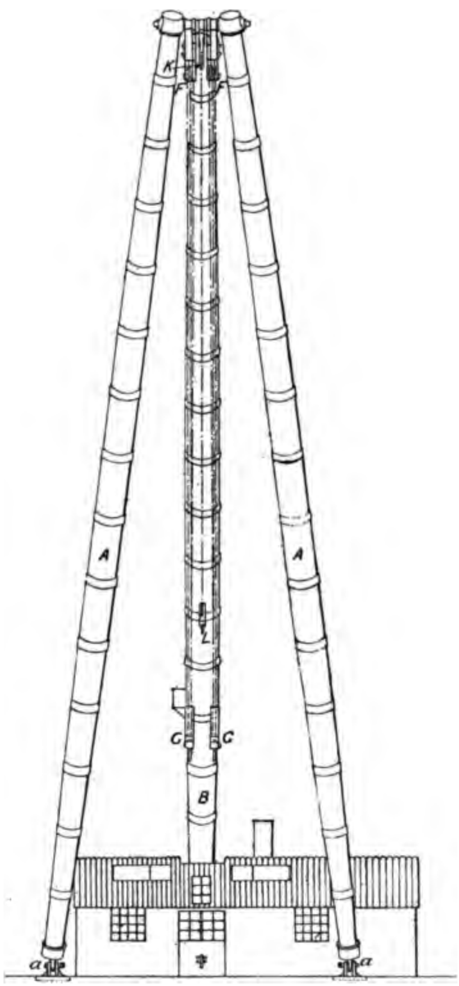


Fig. 165.—100-Tons Masting Sheers.

round top pulleys F to the snatch blocks G below, with four falls of rope, the ropes being anchored to the snatch blocks through which the pins of the pulleys F pass. For lifting light loads, a separate drum H is provided, taking a single wire rope E, 5½ in. in circumference and 580 ft. long. This passes round the top pulley K and the snatch L with two falls, being anchored to the block above. In order to avoid having to traverse the sheer legs by the screw when handling light lifts, a small winch M is provided with a rope N, 3½ in. in circumference and 200 ft. long, attached at the other end to the blocks G. Brakes are provided for the drums and also for the horizontal screw.

The enormous foundation required to ensure the stability of such a crane with 100 tons suspended at maximum radius of 60 ft. is well shown by the drawing, and the large number of hold-down bolts to the screw girders and the winches.

Sheers are also put on board a boat, for convenience of movement about docks and basins, hence termed *floating sheers.*

Sheet Brass.—Used for many purposes, as for vessels of various kinds, and for coverings of domes, for bands encircling lagging, &c.

Sheet Copper.—This is used for various vessels in some departments of engineering, marine, and brewers chiefly. It is either practically pure, or alloyed in the cheaper sheets with zinc. Muntz metal is composed of about 40 zinc to 60 of copper.

Sheet Gauge, or **Sheet Metal Gauge.**—Formerly sheets were ordered indifferently by an old sheet gauge, or of the Birmingham Wire Gauge, between the same numbers of which little difference existed. When the new Imperial Standard Wire Gauge was legalised in 1883, it was ordered to apply to sheets also. This decision, which would if carried out have caused much confusion among manufacturers and workmen, was successfully appealed against by the South Staffordshire Ironmasters' Association. But to standardise as much as possible, a new gauge was built up which differed but slightly from the old. The highest and lowest numbers were taken, and the intermediate numbers were varied by about 11 per cent. difference in thickness. This was issued in March 1884 for the use of sheet and hoop iron makers. The numbers run from 3° to 40, and range from ½ in. in thickness to 0·00386 in. Though the weights are given corresponding with the whole range of thicknesses, the sheets are not sold by weight as are those of lead and zinc.

STANDARD SHEET AND HOOP IRON GAUGE (B.G.).

in March 1884, by the South Staffordshire Iron-sters' Association, for the use of Sheet and Hoop n Makers.

Thickness in			Approximate Weight per Superficial Foot of Sheet Iron in Lb.
Ordinary Fractions of an Inch.	Decimals of an Inch.	Millimetres.	
1/2	·5000	12·700	20·000
...	·4452	11·288	17·808
...	·3964	10·068	15·856
...	·3532	8·971	14·128
...	·3147	7·993	12·588
...	·2804	7·122	11·216
1/4	·2500	6·350	10·000
...	·2225	5·651	8·900
...	·1981	5·032	7·924
...	·1764	4·480	7·056
...	·1570	3·988	6·280
...	·1398	3·551	5·592
1/8	·1250	3·175	5·000
...	·1113	2·827	4·452
...	·0991	2·517	3·964
...	·0882	2·240	3·528
...	·0785	1·994	3·140
...	·0699	1·775	2·796
1/16	·0625	1·587	2·500
...	·0556	1·412	2·224
...	·0495	1·257	1·980
...	·0440	1·118	1·760
...	·0392	·996	1·568
...	·0349	·886	1·396
1/32	·03125	·794	1·250
...	·02782	·707	1·1128
...	·02476	·629	·9904
...	·02204	·560	·8816
...	·01961	·498	·7844
...	·01745	·4432	·698
1/64	·015625	·3969	·625
...	·01390	·3531	·556
...	·0123	·3124	·492
...	·0110	·2794	·440
...	·0098	·2489	·392
...	·0087	·2210	·348
...	·0077	·1956	·300
...	·0069	·1753	·276
...	·0061	·1549	·244
...	·0054	·1371	·216
...	·0048	·1219	·192
...	·0043	·1092	·172
...	·00386	·0980	·1544

.—The weight in steel can be found by adding 2 per cent., or $\frac{1}{50}$ to the weight in iron.

eet Lead.—This is used for tanks for cals, and for accumulators; and by pattern-rs for lining up portions of patterns, both od and metal, when the thickness to be is too little for the fitting of wood. It ployed thus to effect slight alterations in existing patterns, and so save the cost of new ones, and it is used for giving tooling allowances on old or broken castings which have to be moulded from to save the cost of patterns for the same.

Sheet lead is sold by weight, which ranges from 1 lb. to 12 lb. per superficial foot.

Sheet Metals.—These include nearly all metals, and a larger number of alloys in their various grades. They include iron, and steel, lead, zinc, the very numerous copper alloys, and of course the precious metals, gold, silver, platinum, and some others which lie outside the work of the engineer. The property which renders sheet metals of value is that of malleability, by virtue of which sheets can be rolled in the first place, and subsequently raised, bent, pressed, thinned, and thickened locally. Tenacity is a property of equal value, since without this, sheet metal would fracture during the mechanical processes to which it is subjected. Ductility and tenacity are allied properties, but the first named is that by virtue of which a material can be drawn into wire. Neither of the processes of rolling, drawing, pressing, or raising, can be carried out to any considerable amount without the aid afforded by heating and slow cooling. *See* **Annealing**. Without annealing the cohesion of the particles would be destroyed.

There are other properties of sheet metals which, though of value, are less so than those just named. Metallic lustre is not permanent in any of those used by engineers, hence the need of frequent polishing in brass, copper, and tin work, or affording protection by lacquering. Conductivity, of much value in wire, is also of importance in lead and zinc plates, used by electricians. *See* **Storage Batteries**. Fusibility is chiefly of interest in regard to the temperatures at which soldering or brazing may be done. Specific gravity is chiefly concerned with the weights of the sheets, by which the prices are governed.

Sheet Metal Work.—This is carried out in those engineers' shops which deal with locomotive and marine construction, and with brewers' utensils. It is done in copper, and tin plate chiefly, and to a lesser extent in other materials, as zinc and lead. In its entire scope

it involves many subjects, which include geometrical problems, and the projection and mensuration of bodies, the properties of all metals and alloys which are rolled into sheets, the methods by which the various forms are imparted, as by processes of flattening, and bending, raising, and stamping, and by spinning; the methods of union by riveting, and soldering, the forms of joints, and the large questions of machines employed in the various works. Some of these are of less importance than others in the engineers' works. But as the tendency has long been to remove operations from the sphere of hand work to that of machines, the construction of the machines alone gives employment to large numbers of engineering works. Some of the most important of these processes and machines are noticed under their suitable heads.

The problems which the sheet metal worker has to solve include all those which are covered by the term *developments*. That is, the envelope of a body, however intricate its shape, can be marked out by geometrical methods on a plane surface. This is not always strictly correct, because there are cases in which a little extension, or drawing in of the sheet metal at certain localities may be necessary. This only occurs in some sheets that have to be hollowed or drawn, and not in those which have plane faces. Speaking generally, the development of sheets is done by simple geometrical problems, and it is not complicated as the work of the boilermaker often is by the thickness of the plates. Sheets are treated as though they have no sensible thickness, whereas with plates that are bent it is usually necessary to settle which side of a plate has to come within or without. There is no special difficulty in the work of development. It involves a knowledge of the geometry of all the elementary bodies, as prisms, cylinders, cones, spheres, and right and oblique figures. Then the most intricate forms are found to be built up of these, or portions of these, and of intersections of them. Calculation is not so much employed as graphic methods, a considerable number of equal divisions being stepped round the bounding edges of objects, giving total lengths and supplying points of intersection of lines obtained elsewhere. Some examples occur under **Plating**.

It is usual to mark out the actual pattern of an article before taking account of the joints. These are added in the form of seams for lap soldered or riveted joints, or of cramped, or rolled, or socketed joints, or for wired edges.

Weight of Twelve Inches Square of Various Metals, in Pounds.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Gun-Metal.	Brass.	Copper.	Tin.	Zinc.	Lead.
Inch.									
$\frac{1}{16}$	2·50	2·34	2·56	2·75	2·69	2·87	2·37	2·25	3·68
$\frac{1}{8}$	5·0	4·69	5·12	5·5	5·38	5·75	4·75	4·5	7·37
$\frac{3}{16}$	7·50	7·03	7·68	8·25	8·07	8·62	7·12	6·75	11·05
$\frac{1}{4}$	10·0	9·38	10·25	11·0	10·75	11·5	9·5	9·0	14·75
$\frac{5}{16}$	12·5	11·72	12·81	13·75	13·45	14·37	11·87	11·25	18·42
$\frac{3}{8}$	15·0	14·06	15·36	16·50	16·14	17·24	14·24	13·50	22·10
$\frac{7}{16}$	17·5	16·41	17·93	19·25	18·82	20·12	16·17	15·75	25·80
$\frac{1}{2}$	20·0	18·75	20·5	22·0	21·5	23·0	19·0	18·0	29·5
$\frac{9}{16}$	22·5	21·10	23·06	24·75	24·20	25·87	21·37	20·25	33·17
$\frac{5}{8}$	25·0	23·44	25·62	27·50	26·90	28·74	23·74	22·50	36·84
$\frac{11}{16}$	27·5	25·79	28·18	30·25	29·58	31·62	26·12	24·75	40·54
$\frac{3}{4}$	30·0	28·12	30·72	33·0	32·28	34·48	28·48	27·0	44·20
$\frac{13}{16}$	32·5	30·48	33·28	35·75	34·95	37·37	30·87	29·25	47·92
$\frac{7}{8}$	35·0	32·82	35·86	38·50	37·64	40·24	32·34	31·5	51·6
$\frac{15}{16}$	37·5	35·16	38·43	41·25	40·32	43·12	35·61	33·75	55·36
1	40·0	37·5	41·0	44·0	43·0	46·0	38·0	36·0	59·0

e tools and machines used in the sheet trades include a large number, many iich are employed also in the machine and g shops, and by the pipe fitters. But stakes or small anvils, the creases, rels, many of the hammers and blocks are of kinds special to sheet metal work. The punching and shearing machines and the bending rolls are lighter than used by engineers. The rotary shears nly used for sheet metals. The presses a large group, and also the closing and ng machines.

eet Mill.—The mill in which the smaller s are rolled for tin plates and galvanised . The larger sheets used in platers' work by engineers are rolled in small **Plate s.** The sheet mills are of two-high type. olls measure from 22 in. to 24 in. diameter, larger than the older rolls which were for iron sheets. Those used in Birmingham South Wales were from 18 in. to 22 in. eter, and from 3 ft. to 6 ft. in length, e billets or tin plate bars are of small nsions. Billets for large sheets are about . thick, tin plate bars are from $\frac{3}{8}$ in. to thick, and from 7 in. to 9 in. wide, and efinite weights to roll sheets of various Being small, two billets or bars are rolled simultaneously, an exchange going nstantly between the roller at the front, the catcher at the back, one sheet being ed back over the top while the other ing put between the rolls in front. This ore rapid than if the work were done reversing mill, or in a three-high mill.

e sheets being very thin, it is highly tial that the rolls shall be maintained in h degree of accuracy. The rolls are chilled, urned up frequently, usually once a week, h is sometimes done in place. The bearings nade and fitted with great care. Pinions not employed for driving, the weight of pper roll on the lower providing sufficient onal contact to grip the sheets. Adjusts for thickness are made by screwing the oll down, and in the thinnest sheets the ging of the housings is sufficient to allow heets to pass through the rolls.

e effect of doubling is to cause the sheets to become adherent through a film of oxide which forms. They are therefore bent in rolls which are provided with a guide which causes the sheets to bend upwards and downwards in their passage through, so loosening the oxide and effecting their separation. After having their edges shorn, and being annealed, they are left black for tinning.

Annealing is done in boxes of wrought iron or steel of large area and depth, capable of taking several tons of sheets. The covers are luted. About twenty-four hours are required for heating, and three or four days for subsequent cooling.

Sheet Piling.—This is used to keep water out of coffer-dams, and generally to form a solid wall to resist the pressure of water, behind which excavations and constructions can be carried on in the dry. It may also enclose loose or sandy soil. Sheet piles thus differ from common or bearing piles in not having to sustain a superstructure, and the term *sheet* denotes their close continuous fitting.

Sheet piling has until recent years been constructed of timber balks, or half balks, driven edge to edge in as close contact as possible. To ensure such contact the lower ends are cut to a single bevel, which produces a tendency of each pile to be drawn tightly against its fellow. Generally the abutting edges are plain, but they are sometimes tongued. They are maintained in line by means of *wales*, or *waling pieces*, or *shingles*, which are laid alongside horizontally, and supported at intervals by *gauge*, or *guide piles*. Sometimes in dry soil a trench is dug, and the piles are laid in side by side, and the trench refilled.

Ferro-concrete is used for sheet piles. They are made by the same methods as the bearing piles, but the abutting edges have semicircular grooves into which fine concrete or grouting is poured, joining the piles together watertight. The shoes are wedge shaped as in timber sheet piles. The Friestedt piles are built up of channels and zed bars. *See* **Piles.**

Sheet Rubber.—Used for electrical purposes, and for packing joints. In the latter case it is combined with canvas, and is then called insertion.

Sheets.—These include all rolled plates of

iron and steel which are below No. 4 B.W.G. or about ¼ in. thick, as distinguished from **Plates,** which are over that thickness. There are two classes of sheets, those of large dimensions used for constructional work of various kinds, and the smaller sheets employed for tinning and galvanising.

The terms *singles*, *doubles*, and *trebles* or *lattens*, are derived from the successive stages in the rolling of sheets. All sheets between No. 4 B.W.G. (0·238 in.) and No. 20 B.W.G. (0·035 in.) were originally rolled singly, or one sheet at a time only. If required thinner, the sheet was doubled over lengthwise on itself and re-heated and re-rolled in two thicknesses down to No. 25 B.W.G. (or 0·020 in.) doubles. Below this thickness to 27 B.W.G. the sheets were again doubled on themselves, and termed trebles or lattens. Those from 27 to 29 B.W.G. are termed *extra lattens*. As two sheets are now rolled at once (*see* **Sheet Mill**), they are generally rolled singly down to No. 13 B.W.G. before they are doubled, and then there are two doubled sheets going through the mill simultaneously. The doubling may be repeated again for very thin sheets. The rolls run at from thirty to thirty-five revolutions per minute. Annealings and re-heatings are necessary for the thinner sheets. Finally the edges are sheared, and the final annealing done. These are the black plates used for tinning. What are called *bright cold rolled* sheets are prepared from strips, pickled, and annealed, and rolled in oil to gauge. They are used for pens and other stampings.

Sheet Zinc.—Used for various vessels and tank linings in engineering. Weights are given in pounds per square foot, corresponding with thickness by the wire gauge, and as that of sheets 8 ft. by 3 ft. and of various thicknesses.

Shell.—An outer or principal casing, as the cylindrical body of a steam boiler, or of a fire-box. *See also* **Projectile.**

Shellac.—A resin which exudes from the puncture of certain East Indian trees, as the *Ficus indica*, by the lac insect, *Coccus lacca*. The crude product is *stick* lac, and *seed* lac. If this is melted in boiling water, and poured over a cold surface the thin *orange* shellac is produced.

Shellac Varnish.—Shellac is the basis of a good many varnishes and polishes in which other ingredients are included. But the varnish of the patternmaker is made simply by dissolving orange shellac in methylated spirit. Wood naphtha may be used, but it is not so good as spirit. Spirits of wine would be employed but that the methylated spirit is cheaper.

The effect of applying a coat of shellac varnish to wood is to roughen up the grain as the spirit evaporates. This is then rubbed down, and another application of varnish made, to be rubbed down in turn. Two or three coats are required for a pattern. They are applied with a brush. Shellac varnish is also applied to metal patterns. But it does not hold on a polished surface. On such a surface rusting is resorted to if the patterns are of iron. If of polished gun-metal, beeswaxing or blackleading is substituted for varnishing, or nothing is done to the surface.

Shield.—*See* **Tunnel Shield.**

Shifting Link—*See* **Link Motions.**

Shingling.—The work of consolidating the puddled balls of spongy iron drawn from the puddling furnaces, the result being the blooms and slabs, which are then passed on to the puddling rolls. The term dates back to the period when the hammers had not yet invaded the province of the crocodile, or alligator squeezers. In these the bloom is reduced between an upper and a lower jaw. The lower one is fixed, the upper is pivoted at one end, and oscillated at the other by a crank. The top jaw is serrated, and the bloom is entered at the end farthest from the fulcrum, and thrust inwards between the jaws, reduction taking place gradually as the fluid cinder is squeezed out, and the metal compressed. The bloom when ready for the puddle rolls is termed a *shingled bloom*, and the workman is a *shingler*.

Ship Building.—The construction drawings for an iron or steel ship received from the designer are set out to actual size in the mould loft by the loftman. They comprise three views, a *sheer plan* which shows all the lines of length, and height from stem to stern, a *half breadth plan* which shows all lines of length and breadth as they would appear when viewed

above, and a *body plan* or *end view* which 's the lines of breadth and height. These 1 marked out to actual size become a check 1e draughtsman's drawings made to a small . This is termed *fairing* the ship. Then working drawings of the transverse views made on the scrive board, marked deeply a scriber point, and the framework is equently checked by the lines on this board. 1e body plan is marked on the board in ion to certain horizontal and vertical lines h are drawn at right angles with each r, and about 2 ft. apart, and parallel. The contal lines are termed *water lines*, and are contal sections of the ship. The vertical are set off to right and left of the centre of the vessel, and to the full width of the 1. Those on the fore body plan are the *lines*, those on the after body plan are *ck lines*. The fore body and the after may each be in half view only, to right left of the centre line on one scrive board. complete views may be drawn on two e boards. Certain diagonal lines are next rn, each pair meeting at the centre line, bject of which is to cut the frames at right es. The intersections of the frames with e horizontal, vertical, and diagonal lines d the means by which the shapes of the es are obtained. Each frame is numbered, the distance of the intersections from the re lines are measured for each frame. Thus body plan of the vessel is scribed out on the e board. It includes rise of floor, decks, le of floors, frames, keelsons, riband lines, lar bottom, strakes of plating, &c. Lines he sheer plan and the half breadth plan to be laid down for longitudinal dimen- and curves. Although these drawings have extremely complicated appearance, an ex- enced man is able to trace out each element ily in the distinctive views.

1e basis of the work is the keel, which is down first. There are three kinds of keels, bar, the side bar, and the flat plate. The bar s are the older type. The bars are supplied engths of from 30 ft. to 60 ft. and fitted scarfed and riveted joints, the length of being equal to nine times the thickness of The side bar keel is a plated form, extending up to the top of the floor, the side bars being riveted on each face of its lower edge. The centre plates and side bars are made in as great lengths as are procurable. The side bars make butt joints. Flat plate keels are used now for large vessels, to the general exclusion of the older bar keels. A centre plate usually receives the flat plate which forms the keel, the two being united with angle irons along the inner edges. The keel plates are usually doubled for a considerable width amidships. The adoption of this design lessens both weight and labour.

The ribs which stand out at right angles with the direction of the keel plates are termed floor plates, because they support the floor of the bottom of the ship. They abut against the centre plates and are attached with vertical angles, but their connection is reinforced by heel pieces which are reved through triangular holes punched in the centre plates to allow the heel pieces to pass through. The term *frame* relates to the bottom angles of the floor plates, *reverse frame* to the top angles. Over the centre plate comes the keelson. It may be formed of plate and angle, or be a *bulb* bar united to the floor with angles.

Cellular Bottoms.—These are practically universal for all large new ships, combining the advantages of water ballast with safety. They differ in design, but comprise essentially a series of vertical plates stiffened with frames and reverse frames, and having manholes cut to permit of examination. They extend from the keel to the margin plates against which the ribs or frames of the ship are fitted. Intercostal plates are fitted. Connection is made by angles, or by flanging the plates.

Stem and Stern Posts.—These are fitted to the keel ends. They are made of forged iron, mild steel, or steel castings. Before making the stem, a model or mould of it is prepared in wood from the drawing in the mould loft, and the correct curve is maintained by fitting cross-bars. Various lines are marked on it, as the top edge of the keel, if a bar keel, or a flat plate keel is used; the plumb or declivity line of the vessel, meaning that the line is plumb when the stem is in its correct place, lines showing the positions of the heels of the bow

frames, and also lines across corresponding with the positions of the riband lines. If a bar keel is used, a vertical scarfed joint has to be made similar to the keel joints, if a flat keel, a horizontal scarf to fit the dished keel plate. If the stem is to be forged, it is formed by bending it on a bending block, with holes. The shape is marked on the block from the model, and the bar heated in a reverberatory furnace. The scarf is covered with fire-clay to prevent it from becoming overheated. The stem is withdrawn when at a nearly white heat, and secured by the scarfed end to the block with dogs. The free end is pulled round with a winch chain, assisted by levers in the holes. It is secured step by step with pins in the holes in the block, with wedges driven between pins and the stem, and with dogs, the latter keeping the stem bedded down on the block. The lines on the block serve as guides for bending by, or a set-iron is used, being bent to the inner curve, and clamped on the block. The head of the stem is usually set in 1 in. or more beyond its proper shape to allow of the springing out which occurs during cooling. The work is done when possible at one heat, but two may be necessary. After the stem has cooled, the various lines set off on the model are transferred to it, and nicked in with a chisel.

The connection of the stem to the keel is a detail of much importance. The method varies with the form of the keel. A long scarf is used in any case, and the check, or shouldering down of the scarf must come midway between frames. The joints are united with rivets, or with tap rivets in the heaviest stems. The stem thus becomes practically a solid continuation of the keel.

The stern post or stern frame forms the connection to the keel at the stern, which corresponds with that at the bow. It includes in screw steamers the boss for the propeller shaft, and the rudder post, the first being the inner or body post, the second the outer post. They are connected by the sole piece below, and the bridge above. A scarf is allowed for on an extension of the sole piece, coming out beyond the inner post for union to the keel. The top of the outer post is extended to reach either to the transom floor, or the poop deck. An extension is often made at the top of the inner post for additional security.

The forms of stern posts are complicated by the presence of twin screws, which involve the fitting of shaft brackets to the stern frames or the hull. Only in a few cases do the shaft brackets form an integral portion of the stern frame, standing out to right and left therefrom in long arms. Generally they are carried at the ends of long arms or struts which are riveted to the keel, and the shell plating through angle irons, the flattened ends of the struts being the *palms*. These may also be riveted directly without angle irons, and in fact there are several ways of making these joints. To reinforce the shell plates where the attachment is made, it is usual to fit a floor plate or a heavy web beam across the hull at that locality. In some cases the struts are made to penetrate the hull, where they are attached to inside brackets, or are scarfed together.

Two moulds or models are made for a stern frame, one representing it in elevation, the other giving the section of the boss. From this a forging or a steel casting are made. The gudgeons or lugs which receive the pintles for the rudder are forged, or cast solidly with the outer post.

The Frames.—These are the ribs of the ship. They are spaced at from 20 in. to 27 in. according to the size of the vessel. They butt on the keel, and are connected with deck beams and stringers. The sections rolled for frames are channels, angles, zeds, and bulb bars. The bevels of the frames vary, and have to be marked off, or *lifted* at each riband line, and the bevels are marked on bevel boards for the platers to set the frames by, each line being numbered.

The bottom frames are marked off first, the transom frame is next taken, and the stern frames up to the cellular bottom. The side frames are then taken, followed by the bow frames. To set the frames for the floors, the aid of a *set-iron* is employed. This is a bar of heavy section, bent to the curve required, and held on the bending slab with dogs in the holes. The floor ends are set around this after being heated in the furnace, being pulled round by a winch and hammered, while the straight portion is retained against the edge of the set-iron

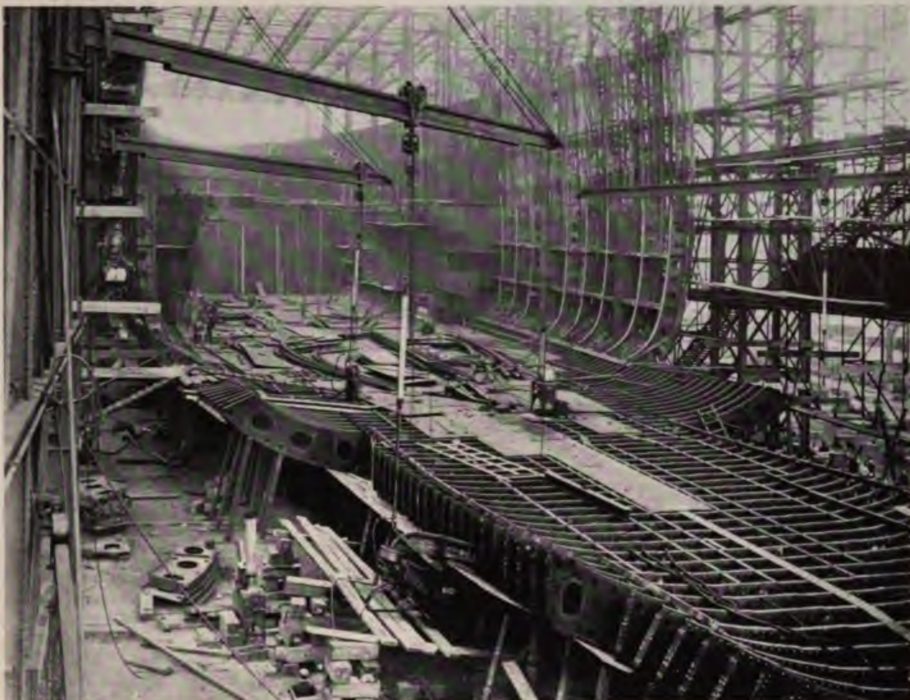


Fig. 167.—Double Bottom of the "Mauretania" with Sides.
(Swan, Hunter, & Wigham Richardson, Ltd.)

Fig. 168.—Stern View of the "Lusitania" under Construction.
(John Brown & Co., Ltd.)

To face page 150.

with pins and wedges. Frames may butt directly on the keels, or, as is the usual practice, against the *margin plates* of double bottoms, or tank bottoms which come out from the keel to right and left to meet the frames. The plate work includes punching the rivet holes, for which there are numerous arrangements, varying with conditions; being spaced from about six to eight diameters apart. Marks are made on the frames corresponding with the positions of decks and beam knees, shell landings, riband marks, &c. The bevel of all side frames is obtuse or open, because the shell flanges in the after body look forward, and those in the fore body look aft. This is done to facilitate the riveting. The frames are bent upon the mould plate, each frame being checked when cold upon the scrive board, and pairs of frames right and left checked for symmetry. Frames are stiffened by reversed angles, or reversed frames. Bevels are usually imparted in a bevelling machine, but if done by hand, a lever or *wheeze bar* is used, which is forked to fit over a web of the angle standing up, the other web, the under web always, being dogged down to the bending block.

Web frames are a form of stiffener to the hull fitted over considerable lengths of a steamer, and are fitted as compensation for the omission of wide-spaced hold beams. The web frame is connected to the shell frame angles by means of web plates, and intercostal plates. Angles form the means of union. These web frames range from 14 in. to 18 in. through, in different vessels. Deep frames are fitted when it is desirable to dispense with wide-spaced hold beams and hold stringers, the increased depth being given to the frame to enable the frame girders to span without assistance from the bilge to the lowest complete tier of beams.

Beams. — These tie the starboard and port frames together and support the decks. They are supported at the centre by pillars, or by deck girders supported in their turn by pillars placed at widely-spaced intervals, and in wide vessels by other pillars intermediate—*quarter* pillars. The pillars reach from the top of the keelson to the deck, and from deck to deck. Beams are united to the frames by knees.

Various shapes are used for beams, varying with the weight of decks and the class of vessel. Most beams are of webbed section, few being boxed up, the exceptions being those under armour-plated decks and in paddle steamers. Common angles are only suitable for small vessels. Tees are used only for light shelter decking. Bulb angles and bulb tees are employed very extensively; so are channels. Built-up forms, being expensive, are used less. These include a tee bar with angles on each side, a plate and double angles forming a joist section with or without plated flanges, bulb bars or bulb tees stiffened with angles next the bulb.

What are termed *sling* beams are often used for carrying the lifting gear over engine rooms, and for vessels of wide beam. They are built up of plate and angle to a joist section. The web plate is made in lengths with double strapped butt joints, treble riveted. Sometimes the joints are welded. A bulb plate is also used with the top and bottom angles forming flanges, so giving the advantage of the bulb stiffening.

There is a good deal of smithing on some beams. It involves cutting them to length, and bevel, and cutting, bending, and welding the knees, and cutting their ends to fit frame sections, imparting the camber, or *round-up* lengthwise, and punching for rivets. A beam mould supplies the lengths, and templets are made for the various details of the work. The various ways in which the knees are made are as follows.

In a plain angle section a portion of the flange near the end is thinned down, and a piece of plate welded on forms the knee. If a bulb angle is used, a length of the bulb is cut off, and a piece of bulb plate welded on to form the knee. Or in bulb and in channel beams a slit is cut some way along about midway in the web, and the end bent to the shape of the knee, and the wide space thus left is filled in wholly or partly with a *crown-piece* welded in to connect the parts of the cut web. Or the knees may be formed as separate plated brackets.

Beams are connected to the frames with knees, which vary in their form with the beam section. The proportions of knees, and numbers of rivets are fixed. Knees are of plate form, welded to the beam, or a plate form of bracket is made independently, and bolted to beam and frame.

Or the beam is bent downwards to a radius to meet the frame, as in rounded poop or forecastle decks.

Carling Beams.—These are short beams, or *half* beams which come in the way of hatches, and are attached to the casing and hatch coaming plates. They are made of bulb tees, and bulb bars, with angles, and are attached with angles at their ends. They are made of similar sections to the ordinary beams.

Stringers, or *Side Stringers.* — These are longitudinal girders which are used to assist the various forms of frames in supporting the shell of the vessel. Modern practice shows a marked tendency to a reduction in size and number of side stringers; it is being realised that owing to their proximity to the vessel's neutral axis they are of little value as contributors to longitudinal strength. It is therefore customary to fit them of a comparatively light form, viz., an intercostal plate whose function is to support the shell plating between the frames, and a frame bar riveted to the inner flange of the frames to prevent the latter tripping.

Hold Stringers.—These are longitudinal plate girders used in conjunction with wide-spaced hold beams or web frames to support the shell plating and give both longitudinal and transverse strength; they are connected to the webs with knees and angles and diamond-shaped covering plates. Bracket plates are fitted under these stringers between the hold beams or web frames to support them and keep them up to their work.

Keelsons.—These are members running longitudinally on the floors. They add to the longitudinal strength of the ship, and connect and maintain the floors level. The centre keelson over the keel is the principal member. Others are *side* keelsons, to right and left, and *bilge* keelsons nearest the sides.

The construction of keelsons varies. A keel plate may extend upwards to form the web of the keelson plate. A foundation plate is fitted on the floors to butt against each side of this, and angles are riveted through the plates, and floors, and through the keelson web. Angles are also riveted along the top edges of the web, and to another covering or rider plate. In other designs the keelson plate is notched to come down through the floors, when it is riveted to intercostal plates. Bulb bars and angles are also used.

Keelsons are made in as long lengths as possible. They are straight amidships, but require setting fore and aft. Their fitting is interfered with by the presence of bulkheads, boiler seatings, &c. The keelsons are passed or *reved* through the bulkhead plates, but they have to be cut short at boiler seats.

Bulkheads.—Reference has been made to the cellular bottoms of ships which serve for water ballast, but which are primarily a means of safety in the event of the outer skin becoming pierced. The division of the hull into watertight compartments by means of bulkheads is another device which conduces to safety. Not only so, but it is an element of great strength, of greater importance in view of the immense size of modern ships. Without these, the huge hulls would be unable to withstand the stresses of weather, but would become distorted and perhaps ruptured. The bulkheads tie the vessel's sides, and maintain the transverse sections intact, besides forming a series of watertight compartments. The bulkhead plates themselves, being thin, have to be stiffened vertically and transversely by means of girders, web stiffeners, and angle, or zed bars, not only to afford transverse strength, but to prevent bulging of plates if an adjacent bulkhead becomes filled with water.

The fitting and spacing of bulkheads is affected by the presence of engine rooms and boilers, and by the position of cargo hatches in merchant vessels. The rules laid down by Lloyd's and other bodies are minute. The object aimed at is to so arrange bulkheads that the flooding of one or two compartments will not cause the vessel to sink in moderate weather. In connection with this, there is the important question of fitting watertight doors, closed at intervals, with other regulations for their efficient working. There is a good deal of lapping and riveting plates, of stiffening frame angles, and caulking of joints in bulkhead work.

Before the decks are plated the beams have to be brought into line or *faired*. The beam ends are, when fitted, united by two bolts only through each knee to allow for adjustments. These are made by bolting one or two ribands on top of the deck beams, or by riveting a

uous strake of upper deck plating on the , and bolting a heavy riband along the . Where openings occur a riband is over the carlings.

next stage is to fair up the beams and gs with timber shores. These start from ottom of the ship, and are continued en decks until the uppermost deck is d. The shores take a bearing on planks bands. The heights are measured by s. The top ends of the beams must come ne with the top edges of bulkheads. The s of the beams must be plumbed to the nd the stem and stern posts plumbed also any deck plates are fitted. The shores n in position until the plating is done. the beams are properly faired, the other in the beam knees are drilled and rivets d.

k Plating.—This is riveted to the tops of ams, forming a rigid connection between The plating of the upper decks is an t element of longitudinal strength, being ernate tension and compression as the lies on the crest of a wave, or over the of a wave. It is therefore in the position irder flange, the bottom of the vessel and wer decks fulfilling the function of the flange, while the middle decks are on or he neutral axis.

k plating is fitted in three or four ways, in and out, or in clincher style, or uous with seam straps at the joints, the being adopted when no wood deck is laid. ck plating stops short of the sides, where s the stringer plating which connects the f the beams, and is connected to the shell by a stringer or *gunwale* angle bar on eather deck only. At a little distance his bar, an angle iron is riveted on the r plate to form the boundary of a wood hen such is fitted, and the space between d the gunwale bar is the waterway.

stringer plates are usually fitted down They range from 5 ft. to 7 ft. wide. holes are marked from the deck beams on wooden templet first. The plates are , and holes are marked for the butt The laying down of the plates proceeds midships fore and aft, after which the deck plating is taken in hand, with lap or butt joints as already mentioned. It is necessary to have these plates perfectly level, for which they are put through the flattening rolls. The deck plating proceeds from the stringer plates towards the centre. The plate edges are pulled over close to the edges adjacent.

In lower decks of steamships the deck plating has to be arrested at the engine room bulkhead. But the stringer plates are carried right through in order to retain longitudinal strength. Here the stringers have to be carried on brackets.

What are termed *panting* stringers are those fitted at the bows of vessels. Their exact position varies with the character of the vessel's bows. Their object is to impart stiffness to the bows when pitching in heavy seas. *Runners* or beam girders are rolled sections which are riveted longitudinally to the under sides of the deck beams to bind them together. The pillars between decks are riveted to the deck runners.

Scantlings.—The various governing bodies lay down rules for the building of vessels to be passed by their surveyors. The following are some of the leading rules of Lloyd's.

The measurements taken as a basis are the length, breadth, and depth. The scantlings are regulated by numbers, which are obtained differently in vessels of different build, as one, two, or three decked, spar decked, turret deck. Tables of dimensions are given to meet all likely cases. Unusual cases must be submitted for consideration. These tables include keels, stems, sterns, and propeller posts, transoms, frames, floor plates, reversed angles on frames, keelsons of the different kinds, stringers, beams, holds, and sailing and steam vessels, pillars, panting arrangements, plating, butt straps, riveting and rivets, bulkheads, steel and wood decks, double bottoms and water ballast tanks, engine and boiler spaces, hatchways, &c.

The photographs, Figs. 166-171, give some idea of shipbuilding methods, the first four showing various views of the giant Cunarders *Mauretania* and *Lusitania*, the largest vessels afloat. The first-named vessel was built on the Tyne by Messrs Swan, Hunter, & Wigham-Richardson, Ltd., the second by Messrs John Brown & Co., Ltd., at Clydebank.

Fig. 166, Plate IX., shows the midship portion

of the cellular bottom of the *Mauretania* in the course of riveting, an hydraulic riveter being seen engaged on the keel plate in the foreground.

The closed-in berth will be noticed, provided with jib cranes along the sides, and travelling electric transporters up under the roof. A further stage is illustrated in Fig. 167, Plate X., showing the fore end with framing in place, and the inner bottom partly plated over. Two jib cranes are seen in use suspending riveters, the one in front being engaged in riveting up the outer plating. A good idea of the immense size of the vessel can be gained from this view.

Fig. 168, Plate X., is a stern view of the *Lusitania* during the building; the curved outlines of the sides to accommodate the propeller shafts may be noted, and also that the deck beams are in place. It may be mentioned that in the case of the *Lusitania* there was no closed-in berth, but hoisting was done by derricks alongside, and the riveting machines were handled by portable jib cranes. The derricks may be seen on Plate XII., Fig. 173.

A fine view of the *Lusitania* is seen in Fig. 169, Plate XI., as she appeared before launching. The graceful outlines of the vessel are well shown, and the lines of the plating joints can be observed. The launching cradles are placed to support the stern tubes.

Figs. 170, 171, Plate XI., give two interior views of a turret steamer under construction at the Sunderland yard of Messrs William Doxford & Sons, Ltd. The construction differs from that of a passenger vessel, the sides being carried inwards at the upper part, and as much space as possible left in the interior of the ship. Specially deep frames are employed without any hold stringers or webs, so as to keep the holds as clear as possible of obstructions. In Fig. 174 wide-spaced side pillars are seen fitted; three small side stringers have yet to be put in place. The vessel in Fig. 175 has large web frames in place of the usual strong hold beams to avoid causing obstruction in the hold. Here the hold stringer and two side stringers are not in place. The vessel is 350 ft. long, and of 49 ft. beam with $26\frac{1}{2}$ ft. moulded depth.

Shipping Dimensions, or **Measurements.**—The cubical dimensions of a machine or packing case. *See* **Tonnage.**

Ship Plates.—Steel plates which have to pass the tests of the principal governing bodies, before being used in vessels under the survey of those bodies. By the Admiralty rule, strips cut lengthwise or crosswise must have an ultimate tensile strength of not less than 26 tons, and not exceeding 30 tons per sq. in. of section, with an elongation of 20 % in a length of 8 in. Bending tests are; strips cut lengthwise or crosswise, $1\frac{1}{2}$ in. wide, heated uniformly to a low cherry red, and cooled in water of 82° Fahr., must stand bending in a press to a curve of which the inner radius is one and a half times the thickness of the steel tested. The ductility of every plate, &c., is to be ascertained by the application of one or both these tests to the shearings, or by bending them cold by the hammer. One plate is to be taken for testing from every invoice, provided the number does not exceed fifty. If above that number, one for every addition of fifty, or portion of fifty.

In Lloyd's register the tensile test is 28 to 32 tons per square inch, and 16 % elongation in 8 in. on plates below $\frac{8}{20}$ in. thickness, and 20 % on those above that thickness. The temper bending test is the same as the Admiralty. The British Corporation is 28 to 32 tons, with an elongation of at least 16 % in 8 in. The Bureau Veritas, the Germanischer Lloyd, and the Registro Italiano, are 27 to 32 tons, with 20 % elongation in 8 in. on plates of $\frac{1}{4}$ in. and upwards in thickness, and 16 % on plates under that thickness. The temper bending test is alike in all.

Ship angles and beams are subject to the same tests as plates. They may in some cases have a ton more of tensile strength, provided they fulfil the other conditions named.

In some recently built high-class ships a special high tensile steel has been used to lessen weight. It ranges from 36 to 40 tons tensile stress, with an elongation of not less than 20 % in a length of 8 in.

Ship's Winches.—These are crabs actuated by a pair of steam cylinders, and made in various powers, for lifting cargoes in and out of holds, and used in conjunction with a derrick pole. They will be found treated under the general head of **Winches.**

Shipyard Cableways.—At the present time these are in close rivalry with cantilever

Fig. 169.—The "Lusitania" ready for Launching. (John Brown & Co., Ltd.)

Fig. 170.—Turret Vessel under Construction.

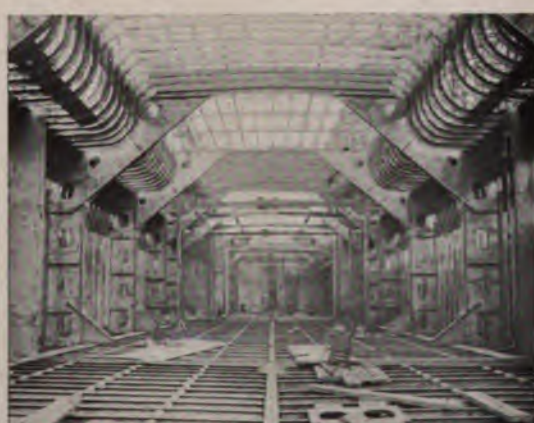


Fig. 171.—Turret Vessel under Construction.

(William Doxford & Sons, Ltd.)

To face page 154.

cranes and derricks for shipyard service. A few years ago cableways, though becoming common in American shipyards, were not installed in English ones. The Palmer Co. were the first in this country to adopt the system. It is held by the advocates of the cableway system that not only is their first cost less than that of cantilever cranes and derricks, but that their upkeep is less. Also that they serve the platers much more efficiently than the cranes do, being more mobile, and so avoid the use of trolleys and tackle on the decks. These installations would not have been practicable in the pre-electricity days. But the conductors and motors supply a light and mobile means of utilisation of power without the heavy shafts and gears required in steam-driven cranes.

The following is a brief account of a shipyard cableway, Fig. 172, Plate XII., erected in the Palmer Co.'s yard at Jarrow. It has been so successful that another and larger installation has been built.

The cableway comprises three units, or three cables stretched between carriages about 500 ft. apart. The hoisting trolleys travel fore and aft along the building slip on these cables. The end carriages traverse with their cables across end girders carried on columns at the ends of the berth. The conception embodied in this was a bold one, and was pronounced impracticable by some firms who were asked to tender. There was the anticipated objection to the great amount of sag, due to the stretch of 500 ft., being 18 ft. in the middle, and the difficulty of traversing both end carriages 500 ft. apart simultaneously without cross-working occurring, for the connection between them was not rigid, consisting only of the ropes. Actually no trouble has been experienced from either cause.

The cableways are suspended from cross girders at a height of about 100 ft. on girders carried on steel columns at each end of the building slip. The columns are of light design, comprising steel members and lattice bracing. Local conditions prevented carrying long guys from the columns, and therefore the columns were set at a considerable inclination from the vertical, 55° and 62°, at each end respectively from a horizontal line, and leaning away from each other above. End guys come perpendicularly to the ground, and these with the effect of the inclination, and the weight and tension on the cables and load trolleys practically counterbalance. The guys, of steel wire, are 6½ in. in circumference. They are anchored into concrete. The columns are each secured to a seat of mild steel in a concrete foundation, with a central bolt 8 in. in diameter. The foundations each measure 16 ft. square, and contain 140 tons of concrete.

The columns are spaced 94 ft. apart, and surmounted by cross girders, steel plated with lattice bracing. There are two girders 100 ft. long uniting each pair of columns at the ends, and having a clear space between, 4 ft. wide, to permit the trolley cables to traverse across the width of the building berth. The cables, of which there are three, independent of each other, are attached at each end to a carriage which travels on rails on the cross girders, so that there are six carriages in all. Each carriage carries a 12 B.H.P. reversible motor, which is geared through worm and spur gearing to the axles which carry the trolley wheels. These motors are controlled simultaneously from the operators' trolley on the cable, and the carriages are traversed at a rate of 25 ft. per minute.

The load carriages which run fore and aft along the cables, and in which the operators sit, each contain a 35 B.H.P. reversible motor. This provides power for the hoisting and travelling motions. The maximum load lifted is 3 tons at 100 ft. per minute; 1 ton is lifted at 150 ft. per minute. The longitudinal travel takes place at about 400 ft. per minute.

The current is conveyed to the motor from overhead copper cables suspended between the end supports. Suitable collecting arms and connections are made to each carriage. The hoisting motion is effected through friction and spur gearing to a drum which runs loosely on a hollow steel shaft. The load is lifted through a four-part wire rope, passing round a two-sheave snatch block. A mechanical friction brake is fitted.

The longitudinal travelling motion is derived from the motor, through friction and spur gears to the travelling motion shaft, on which a rope drum is keyed at each end. Two wire travelling

ropes are stretched from end to end for each cableway, and each is wound on its drum a sufficient number of times to prevent slip in the opposite direction to that in which the carriage is moving. This movement also is braked.

Two controllers and resistances are fitted, one for starting, regulating the speed of, stopping and reversing the motor on the load carriage, the other for similarly controlling the motions on each end carriage. Automatic cut-outs are fitted to each live wire, so that in the event of breakage the current is instantly cut off.

Each main cable has a breaking strength of 175 tons. They are $7\frac{3}{4}$ in. in circumference, made of steel wire having an ultimate tensile strength of 75 to 80 tons per square inch, built up of six strands with nineteen wires in a strand. The end girders are further tied by two horizontal stays of wire rope $5\frac{1}{2}$ in. in circumference. There are also the two travelling ropes $1\frac{1}{2}$ in. in circumference to each cableway.

Shipyard Cranes. — This relates to the cranes used in the course of construction of ships' hulls while on the launching ways, and to those employed in a graving dock, or a fitting-out slip, after launching. Work must be done both on the building slips, and afterwards. Cranes are used which fulfil the varied requirements of building and fitting out; fixed, portable, jib cranes, and derricks, overhead travelling cranes, cantilever cranes, heavy and light, endowed with greater or less degree of mobility.

The earlier cranes used were **Sheer Legs** and derricks. The first named are seldom built now on account of their immobility. They are used for lifting masts, boilers, and engines into the vessels after launching, but as they have no movement laterally, vessels have to be warped along to accommodate the crane.

A type of sheer legs is made by a Duisburg firm, in which the legs are cranked near the top. This permits of bringing the legs far enough back from the quay wall to permit objects to occupy the quay, clear of the legs, and prevents the legs from contact with the bulkheads of the vessel, so allowing the latter to be brought up close to the quay wall. The legs are built of lattice bracing, so lessening dead weight.

Derricks are better than sheer legs, and have been, and continue to be used extensively. But it is rather unusual to fit them now in shipyards which are being newly equipped, because other classes of cranes fulfil the required conditions much better. A derrick has a long reach of jib, and it usually slews, and thus commands a large area. By erecting several derricks, a long building slip, or fitting out basin can be well equipped, and vessels of moderate dimensions covered. But the growth in the dimensions of vessels has been so rapid in recent years that the derricks are now unable to deal with the largest, and the result has been great developments in newer designs, such as the hammer or tower type, the cantilever, the combined traveller and jib crane, bent jib cranes, and cableways.

Fig. 173, Plate XII., shows two electric derricks supplied by Messrs Sir William Arrol & Co., Ltd., to Messrs John Brown & Co., Ltd., who first employed them in building the *Lusitania*, the double cellular bottom of which is seen in the view. The load is 5 tons, which can be hoisted to a height of 120 ft. above the ground level, and slewed through 180° at a radius of 35 ft. from the mast centre. Each mast is 6 ft. square at the centre, tapering off to 18 in. at the ends. There are four wire-rope guys attached to the top of the mast, and one below the jib foot. The jib stands at an angle of 45° and is slewed by a motor on the attendant's platform, which stands 95 ft. above the ground level. The hoisting is performed by a winch having a 30 HP. motor, set on the ground, the rope passing up inside the mast, through the jib foot pin, and then around a guide pulley to the jib head pulley. There are two lifting speeds, 90 ft. and 210 ft. per minute.

Travelling Gantry Cranes.—A crane of this design was erected at Messrs Harland & Wolff's for the building of the *Oceanic*. It was designed chiefly for carrying the hydraulic riveting machines, and is broad and high enough to span vessels. The height is 98 ft. measured to the under side of the cross girders, the clear width is 95 ft. Three hydraulic travelling cranes run on the cross girders for carrying the portable machines, the maximum load being $7\frac{1}{2}$ tons. At each corner is fitted a jib which

Fig. 172.—SHIPBUILDING CABLEWAY. (Palmer's Shipbuilding and Iron Co., Ltd.)

Fig. 173.—SHIPBUILDING DERRICKS. (Sir William Arrol & Co., Ltd.)

To face page 156.

swings through an angle of 180°. They can lift a plate, &c., up to 4 tons in weight from the outside, and swing it over the vessel at a radius of 40 ft. without moving the gantry.

Overhead Travelling Cranes.—These are used at the Vulcan Shipbuilding Yards at Stettin. Two cranes running side by side are necessary, to avoid the too great span of a single crane. But as a central supporting gantry would prevent lifting being done along the centre just over the keel, one crane is made about 6 ft. longer than the other to cover that area. The lift is 4 tons, and the longitudinal traverse is 262 ft. a minute. Electric driving is adopted.

Messrs Swan & Hunter use travelling cranes, with the addition of longitudinal jibs below the cranes. Their building berths are roofed in as a protection against the weather.

A modern shipbuilding berth equipment is shown in Fig. 174, Plate XIII., made by Applebys, Ltd. A steel structure is arranged to span the entire width and length of the building slip; this structure carries a combination of overhead travelling cranes and side walking cranes arranged in such a manner that the shipbuilding material may be quickly and easily brought into position, the cranes being used either separately or in any combination to suit the various squads of men or the varying loads to be handled.

In the particular equipment illustrated, which was photographed whilst in actual use in the construction of a battleship, the vertical steel members are spaced 108 ft. apart, and are 140 ft. high, the total length being 750 ft. The tops of the verticals are tied together with lattice girders in order to preserve a correct gauge for the travelling cranes.

There are two overhead electric travelling cranes, each of 15 tons lifting capacity; they span the entire width of the berth and command the whole area; the driver's cabin is located at the centre of the span. The speeds are as follows:—Hoisting full load, 40 ft. per min.; cross traversing, full load, 220 ft. per min.; travelling, full load, 500 ft. per min.

There are four electric walking cranes, each of 5 tons lifting capacity; the radius is 30 ft. and the height between top and bottom rails is 24 ft.; the wheel base is 20 ft. The speeds are as follows:—Hoisting full load, 60 ft. per min.; slewing, 300 ft. per min.; travelling, 250 ft. per min.

All the cranes were tested with an overload of 50 per cent. in all motions, each motion is operated by a separate electric motor, all the gearing is of steel, cut from solid blanks. The whole arrangement satisfies all the requirements necessary for the rapid and efficient construction of vessels, the material being handled with the minimum delay, whereby the fitters and platers are regularly supplied with material as and when required.

Cantilever Cranes.—These are used over the shipbuilding berths at Barrow-in-Furness and many other yards. Each crane at Barrow serves two building slips, the cantilever arms reaching over on opposite sides. These are illustrated in Vol. III., Plate IX., Fig. 109. A tall trestle erected midway between the slips affords the runway for the cranes. The cantilevers cover the entire width of the vessels on each side of the trestle, the total span covered by the hook between the extremes of the cantilevers being 190 ft. The height is 102 ft. in the case of one crane, and 95 ft. in that of another. The motions are all worked by an 85 HP. electric motor which travels the crane along the trestle track, travels the trolley along the cantilever arms, and lifts the load, the lowering being done by gravity with brakes. The rate of travel varies between 400 ft. and 700 ft. per min., the trolley travel from 400 ft. to 800 ft., the hoisting from 100 ft. to 600 ft. The trolley is connected to the winding drums by wire rope. Hoisting is done by a single drum. The maximum lift is 7½ tons at extreme radius, and about 13½ tons at a radius of 60 ft. from the centre. Counterbalancing is effected by a travelling balance weight connected by ropes to the trolley, and automatically drawn to a position on one arm corresponding with that of the load on the other.

A cantilever crane of similar outline, but with the hoisting mechanism modified, is used for handling the plates in the yard. The radius is larger, and the height less than the cranes over the berths. The total radius is 318 ft. 3 in. The trestle is built wide enough, and open, to allow of pieces 60 ft. in length

being carried through the pier without turning them. The crane runs on a double track of 30 ft. 6 in. centres. An 85 HP. motor is used. The travelling speed of the crane along the track is 300 ft. per minute, the trolley travel anything up to 750 ft. per minute, the rate of hoisting 200 ft. per minute, the maximum load being 5 tons.

The Brown Hoisting Machinery Co. have erected a good number of these cantilever cranes in American shipyards.

The cranes for putting in machinery in the graving dock, or fitting-out basin must be much more powerful than those which are required for handling the plates and frames used in building the hull. Cranes of from 50 to 120 tons are required for this work. This is the kind of work for which sheer legs have been used, or preferably derricks.

Jib Cranes.—One of the largest cranes is fitted at Glasgow by Cowans Sheldon & Co., for the accommodation of the shipbuilders in the vicinity. It lifts 130 tons maximum at 2 ft. per minute, at 65 ft. radius; or 60 tons at 4½ ft., at 69 ft. 9 in. radius. The heavy lifting is done by eight wire ropes 2½ in. diameter. The main hoisting drum is 5 ft. 2 in. diameter by 10 ft. in length, with turned grooves. It weighs 10½ tons. Separate sets of engines are used for light and heavy lifts. The crane with its kentledge weighs 370 tons, 120 tons comprising castings. The jib, of twin tubular type, weighs over 90 tons. The crane stands 110 ft. above the level of the quay. The crane slews on a roller path 33 ft. in diameter. The live rollers in the slewing ring number seventy-five, 14 in. in diameter at the larger end; they weigh 10½ tons, and are, like most of the castings, of steel, mild steel being used for the plated work.

Another large crane is one built by Tannett Walker & Co., for Chatham Dockyard. It lifts 160 tons by direct-acting hydraulic power at a radius of 75 ft. 3 in. There is a lighter lift, up to 30 tons by wire rope. The roller path is 45 ft. 4 in. diameter. There are three pairs of steam engines; one of which pumps water for the hydraulic cylinder, another set rotates the crane, the third set lifts the light loads. The crane weighs about 500 tons, stands 125 ft. high above the quay level, and was tested to 320 tons.

A 120-ton steam derrick crane is erected at Sunderland by William Doxford & Sons, Ltd., for their own works. It lifts 120 tons at 50 ft. radius, and swings it through an arc of 227°; 70 tons at 80 ft. radius, and 30 tons at 100 ft. radius, and swings it through an arc of 240°. It will reach over the width of two vessels lying alongside each other. There are two drums, the lower one for the heavy lift, from 50 to 120 tons; the upper drum is divided into two parts, one half for the light lift, the other for luffing the jib. All three are driven by worm gears. Wire rope 2¼ in. diameter is used for lifting and luffing. Each motion is driven by its own separate pair of engines, making four engines in all, which are supplied with steam at 90 lb. pressure through a pipe brought up through the central pivot. The hoisting speed of the heavy lift is 5½ ft. per minute, that of the light, 37 ft. per minute.

A question of erecting cranes for putting machinery on board ships in basins is that of fixed, *versus* portable designs. The load imposed by such cranes on quay walls is enormous, and foundations for fixed cranes are very costly. But it is easier to lay down a good foundation for a fixed crane than to build a whole quay wall strong enough for a portable crane. For this reason some prefer a **Floating Crane**.

Hammer Cranes.—These are so named because of their crude resemblance to a hammer, and also *tower*, and *giant* cranes. The jib is of double cantilever balanced type, the load being racked along on the longer arm, and the balance weight being carried on the other or shorter arm. The upright post is revolved, and is supported by an encircling framing, usually of trilateral form. The method of operation is by separate electric motors for the different motions, by which alone the construction of such cranes of sufficient lightness is rendered possible.

An example of an electrically operated hammer or giant crane for the fitting out of vessels after they have left the building slips is shown in Fig. 175, Plate XIII., made by Applebys, Ltd.

Fig. 174.—Shipbuilding Gantry with Travellers and Side Jib Cranes. (Applebys, Ltd.)

Fig. 175.—60-Ton Hammer Crane. (Applebys, Ltd.)

To face page 158.

It is constructed for a working load of 60 tons at a radius varying from 18 ft. to 60 ft.; the height from the ground level to the top of the crane girders is 75 ft. The crane consists generally of a revolving cantilever mounted upon a rectangular steel tower, the top of the tower being furnished with a live ring of rollers; a traversing carriage or crab moves along the cantilever to adjust the radius of the lifting tackle. The machinery is assembled at the tail end of the cantilever and is provided with a suitable house; ladders and handrailings are fitted to render all parts of the crane accessible.

The movements of lifting, slewing, and traversing are each performed by a separate electric motor, the speeds being as follows:—Hoisting full load, $7\frac{1}{2}$ ft. per min., with a change gear to hoist loads up to 15 tons at 30 ft. per min.; traversing the carriage along the cantilever, 40 ft. per min.; slewing, 300 ft. per min. measured at 60 ft. radius.

As an instance of economy of ground space, the particular crane referred to has a power house located in the rectangle formed by the legs of the tower. This power house not only provides electrical energy for the crane, but also for the machinery in the adjoining shop.

An electric hammer-head crane of 150 tons capacity is shown in Fig. 176, Plate XIV. It was built by Messrs Sir William Arrol & Co., Ltd., for the fitting-out basin of Messrs John Brown & Co., Ltd., at Clydebank. The tower is composed of four legs, standing on cylinders sunk 75 ft. into the ground; the width at the bottom is 40 ft., tapered off to 35 ft. at the top. Lattice bracing ties each corner leg, and on top of the frame is carried the roller path, supported by girders. The path is 35 ft. diameter, and seventy-five steel rollers, 14 in. by 14 in., take the weight of the revolving portion, while a steel centre-pin, 14 in. diameter and 13 ft. long, passes through the centre. The slewing rack stands outside the lower path, and has teeth of $5\frac{1}{3}$ in. pitch. The jib is composed of two lattice box girders set 14 ft. apart centres, and the depth varies from 26 ft. over the tower, to 15 ft. at the tail, and 7 ft. at the other end. The jib carries a jenny by four lines of rails, and the machinery for operating is carried at the tail end, to assist in counterbalancing, in addition to which there are two tanks holding altogether 86 tons of ballast. There are three barrels, one for the main lift, one for a light lift of 30 tons, and a third for racking the jenny. Both magnetic and hydraulic brakes are provided for lowering. The slewing motor and gear is placed at the front underneath the jib, and the attendant's cage is slung immediately in front of this. Some of the speeds are here given: 150 tons can be hoisted at the rate of 5 ft. per minute, and 100 tons at 7 ft. 6 in. per minute; the auxiliary lift of 30 tons at 12 ft. 6 in., and $7\frac{1}{2}$ tons at 50 ft. per minute. Racking is done at 40 ft. per minute, with a 150-ton load; slewing at the rate of one revolution in ten minutes, carrying 150 tons, and 30 tons in five minutes.

Shoe.—Anything which forms a termination or abutment of a member, as the driving end of a pile, the abutment blocks which receive the ends of leaf springs, a brake block, the ends of sheer legs, or derrick masts, or guys, or jibs, and similar uses.

S-Hooks.—*See* **Lifters.**

Shooting.—Planing the edges of timber joints.

Shooting Board.—A couple of pieces of board superimposed, the upper one narrower than the other by about the width of a plane. A piece of wood laid on the upper piece and against a stop, has its edge shot by a plane laid on its edge on the lower piece. The advantage is that the edge is planed square with the face.

Shops.—The practice of mechanical engineering is not that of an isolated trade, but of several trades, which on first thoughts would appear to have little in common. In a large typical works the different shops comprised within its area include the following:—

1. *The Pattern*, or *Model Shop*, in which the patterns of all work that has to be made by moulding and casting in metal are prepared, mostly in timber, but many in iron or brass.

2. *The Foundry*, which includes several departments. Steel, iron, brass are cast in different shops by different groups of men, who are specially trained therein. In each there are sub-departments corresponding with light and heavy castings, with green sand, loam, and cores; with hand work and machine work, and often with

distinct classes of castings, as cylinders, chairs, brake blocks, &c.

3. *The Forge*, or *Smithy*, embraces work done in wrought iron and steel at the anvil, or under power hammers, or steam hammers, using dies as matrices for producing the forms of forgings by pressure, without tentative formation at the anvil, or in some cases as an adjunct thereto.

4. *The Turnery.*—Here cast and forged work is brought which requires to be turned in lathes. This is usually subdivided into light and heavy, and further into boring and turning, and again between ordinary lathes, and automatics, and turret lathes.

5. *The Machine Shop*, which comprises all the machine tools not included in the turnery, as planing, shaping, slotting, drilling, boring, milling, gear cutting, and grinding. It is subdivided into many groups, and is generally the most extensive department in the works.

6. *The Boiler Shop.*—In this the manufacture of steam boilers is carried on. It includes several sub-departments, since no one group of craftsmen carries such work through to completion. Also, the methods, the plant and machinery and the men themselves differ with the great groups of boilers made, as locomotive, marine, Lancashire, vertical, and so on.

7. *The Plating Shop.*—This is devoted to the manufacture of work built up in iron and steel plates, and sectional forms. Its methods and tools are generally those of the boiler shop, modified by the differences in the character of the work done. Sometimes the two classes of operations are carried on in the same shop, and by the same sets of men, platers, drillers, riveters, &c. But generally in large works the departments are distinct.

8. *Coppersmithing* is an important department in locomotive and marine shops, and in brewers' engineers, in which the methods are those involved in the working of copper sheet into numerous shapes.

9. *Tinsmiths.*—In some shops these form a large department. Stamping and drawing presses form part of the equipment, and soldering is done extensively. There is much of this in railway shops, and in brewers' engineering.

10. *Carpenters, Joiners*, and *Cabinetmakers.*—This department is a large one in many works. It is so in some crane and lift shops, and in railway carriage, and wagon shops, and in shipbuilders' yards. A considerable amount of wood-working machinery is utilised in railway shops. In most firms the *packing case* department is of fair size.

11. *Testing Department.*—This is a very important section of the works, and to which much more attention has been given than formerly. In modern shops it includes an electrical testing plant. Ordinary plants are adapted to the special manufactures of a firm, and include steam, water pressure, and pumps. The testing of steam engines and boilers involves a large amount of careful calculation, bearing on fuel efficiency, and on steam consumption, while the action of the steam in the cylinder is read on the indicator, which is the engineer's stethoscope. All large machines of all kinds; tools, cranes of every kind actuated by steam, water, compressed air, or by belting are tested either in the shops, or if large, out of doors, to ascertain if they fulfil the engineers' specifications. Bridges and girder work generally are subjected to dead, or to rolling loads, corresponding with the nature of the stresses which they will have to endure. There is also the testing of materials which all large firms now possess. The testing machines are numerous, and specialised, for ordinary specimen pieces in metal, to be subjected to tensile, compressive, and torsional stresses. Chains, springs, and other manufactures have special machines.

12. *Painters.*—These take metal and wood work in hand after testing. Some engineers are very particular in their specifications as to the composition and quality of the paints used, and the use of boiled oil to precede the application of paints. In the railway shops the coats of paint are rubbed down, and finally polished. Some of the large firms have a shop for grinding as well as mixing their own colours.

Shop Stands.—Provision is made in good modern shops for the storage of materials, and of partly finished work, as well as tools and appliances, upon stands, or racks, either fixed or portable. The portable types are handy for

use among machines, where it is either desirable to transfer the work bodily by wheeling the stands along, or where occasional change of position is required, to suit the lay-out of lathes and machines. The largest classes of stands are those used in the machine shop and smiths' shop for storing bars, and other material. The construction includes uprights and transverse horizontals, set slightly on the incline, to prevent the bars from rolling off. Wooden uprights and cross-bars are often used, but steel is more durable and tidy. Bars and other sections are often stood upright when of considerable length, resting against rods standing out, to form divisions against a wall. In the machine shop, when a supply of bars is carried close at hand to the lathes, &c., stands of triangular form are employed, with arms to support the bars. In the best arrangements, these stands occupy the central aisle of the shop (provided it is not required for a track) and the lathes flank each side.

The shorter and more easily handled pieces, such as lengths of bar cut off, and castings and forgings ready for tooling, are laid upon the flat surfaces or trays of stands built up of cast iron or of piping. The simplest stands are comprised of two cast-iron ends, of **A**, or of parallel shape, tied together with bolts, and supporting three or four trays of shelves of wood upon ledges. The advantage of wood is that it does not damage the work, an important consideration, if finished pieces are being dealt with. It is however liable to become soaked with oil, which is not the case with iron. Trays of cast iron with upturned edges are frequently mounted upon tubular uprights, this forming a cheap and neat construction. Slots or recesses are often cast around the edges, or underneath, to receive the heads of numerous bolts, which are thus stored ready for use on the various machine tools, instead of being thrown down in a heap on the floor. When the stands have to be moved about, castors are fitted to the legs. Many stands have been constructed recently of stamped steel in place of cast iron, as being lighter, and free from risk of fracture. When tools and delicate appliances are stored on stands, it is better to provide a lock-up drawer, slung on runners beneath the top tray. Provision for the bolting of a vice is included in some stands, Fig. 177, when the nature of the work renders this desirable. This stand also includes a rack for files, &c.

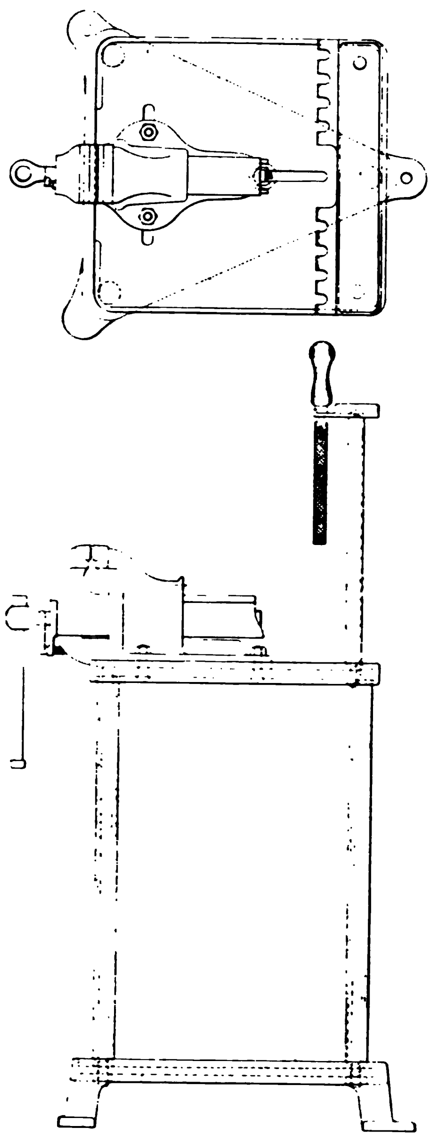


Fig. 177.—Shop Stand.
(J. Parkinson & Son.)

Repetition work which is always going through the shops can be best dealt with by special types of stands; thus turned work, or pins,

spindles, shafts, &c., of moderate length, can be stuck upright through holes in a top and bottom board in a frame mounted on runners, the stand being wheeled away with its load as soon as filled, and brought back empty, or with a fresh lot of spindles for turning or grinding. Such a stand is most useful in the finer classes of work, where damage caused by knocking the objects would be objectionable.

Shop Systems.—Much more attention is being given to this subject now than formerly. It has been too greatly neglected in the past. Many works which made a profit in the old days could not do so now in face of the severer competition which exists. Output was often thought to be in direct proportion to physical activity, and inconsistent with the best workmanship. Now it is understood that brains and system accomplish more than hustle, and that the highest economies are compatible with very great accuracy. Machines of course play a leading part in this, but behind the machines there lies the system of the shop.

Shops may be classified in three broad groups, the general, the specialised, and the intermediate. The systems of each differ from the others.

General Shops.—In these the predominant feature is, that the firm takes any kind of work which comes along. Such shops fill an essential place in country towns and districts, while there is scope for them in crowded cities. Much of their work lies in repairs. Much of it comes from old customers who prefer the work of the firm to which they have grown accustomed. The best men are mostly all-round hands. There is little of minute subdivision of tasks. Men are changed frequently from one job to another, and they acquire a wide but accurate knowledge of all the work which comes to the firm, and are able to tackle unexpected and novel tasks. It was the old training and experience, of which comparatively little remains to-day.

Specialised Shops.—But many of the older general shops have drifted more or less into specialities, thus: one by one, groups of articles have been abandoned under the pressure of the competition of firms who have made these articles specialities, and who are able therefore to supply them more cheaply than the older firms can produce them. Attention has been concentrated on articles which have been retained, and generally the methods of the specialised shops have been introduced to a greater or less extent. Also the work has been divided amongst different shops or groups of men. In this way some firms have become specialists, though still retaining a good number of different articles of manufacture. Others, and especially those where a large volume of repairs is done, have only partially adopted the newer methods.

Very largely the system of a shop is controlled by its extent. A small one is run on different lines from a very large one, or from one of medium dimensions. The feature of the first is that all the work can be carried on under one roof, or in buildings immediately adjacent, that of the second is that departments are extensive and occupy large areas widely separated. Obviously the methods of supervision of the first, which is mainly personal, are insufficient in the second, which must be largely clerical with some amount of red tape involved. In the shops of intermediate size the two systems overlap.

Another feature which modifies a system is the size of the articles which are manufactured. The system which is adapted to work in which the pieces are few and of a massive character is unsuited to that of small dimensions. There is, for instance, little in common between a marine engine works, and one manufacturing brass goods. In the first there is little storage and booking; in the second, fittings and parts of fittings are made in sets and stored. Piece work predominates in the second, but not in the first.

A feature which characterises modern systems is the large place which machines, gauges, templets, and jigs occupy by comparison with the systems which are past or passing. No shop can now afford to neglect the economies which result from the judicious employment of these aids. There are gradations in their use, which reach their highest developments in the interchangeable system. But in classes of work to which this is only imperfectly adaptable, templets and gauges supersede hand methods. Large dimensions generally set a

to the use of jigs, though not of templets ;auges.

ganisation is an essential part of a system. now recognised that this should be alised in the office, whence all orders must ate. In the past very much has been left e initiative of the foremen, and although esults have often been good from the inical aspect, the practice is inconsistent keeping complete office records of all s, and of complete office control over ials and labour. All orders, including inutest details, should emanate from the ng office, and the commercial offices in the of complete drawings and written instruc- and the system must be carried out in ie sub-departments of the works. This es questions of drawings for separate , order books and numbers, relations of gers, foremen, and workmen, and system yment.

op Tools.—Denotes tools and appliances are used in the shops as necessary to the plishment of work, or which expedite it. are used in all departments—foundry, y, boiler shop, machine, and fitting, and ng shops. They embrace all kinds of es and tackle, light and heavy, templets, gauges, blocks, everything in fact which is included in the regular machines and .

the small and in the general shop the ng of shop tools is often carried on under erent system than it is in the large and lised ones. In the former these appliances ft in the hands of men and foremen, to be ied by them and carried through without nce to the offices. An idea occurs to a nan or to a foreman. The suggestion is efore the manager, or active employer, liscussed. A verbal sanction is given to naking of the tool or jig, and it goes on ally without any sketch or drawing save which may be made by the foreman, or man. Material and time are charged either ols for the job for which the jig is made, is the proper way to charge, or an open nt is kept in the offices for shop tools, and are charged to that, irrespective of the o which they belong, which is a loose way when applied to the machine shop. The justification of the latter is that tools once made are frequently kept for future general use, and their charge should therefore be spread over all the work done, and a percentage of cost added to every job.

But in a fair system there is a place for both, and the settlement of such matters must be made after a consideration of each individual case. If a tool is of so special a character that it is unlikely to come in for other jobs, then its full charge should be made on that for which it is designed. But if it will do duty for future orders then it may be made a general charge on the shop tools. The following may be given as examples of what is meant.

If a drilling templet is made for a certain size of flange in a class of work that will be repeated unchanged for a term of months or years, then it may go down to general shop charges, the cost being infinitesimal on the first order. If a set of tools is rigged up for machining a spindle of a common type, the cost may be charged to the department and not to the first order. If moulding boxes are made for a new order, they may often, with or without slight modifications, be retained for general service, and then a small percentage of the first cost only should be charged to the job. If a bending block of a certain size is wanted in smithy or boiler shop, unless its form is very special, it should be charged into general shop tools. If a set of patterns is made for a job to be often repeated, the cost should not in fairness be lumped on the first order given.

On the other hand, if a jig has to be made for an unusual form, or for an occasional job which is not likely to be repeated, the charge to general shop tools is unjust, and the whole charge should be borne by the order for which it is made. So with special bending blocks, awkwardly shaped moulding boxes, as those with curved or diagonal joint faces, or of tapered or angular outlines; so also with patterns for single orders, and patterns for shop tools which once made may never be repeated. The frequent custom in works is to destroy such classes of tools after they have served their purpose rather than lumber up stores or yard room with them.

Shoring. — Supporting or blocking up massive work with props or struts of timber. It is adopted in all kinds of heavy erections and in shipbuilding.

Short Columns.—Denotes those in which the length is less than thirty times the external diameter. They fail by a compound strain—compressive, and transverse. The breaking strength, w, of a long column of similar type is first found, and then that of the short column is deduced by the formula :—$w = \frac{Wc}{W + \cdot 75c}$ where W is the breaking strength of the long column, and c the crushing strength of the material of which the column is made, × the sectional area of the column.

Short Heat.—Making a short length of a bar hot in a smith's fire for the purpose of localising work on it, as in upsetting and welding. If a long portion were heated, it would become bent or distorted by the work done. The portion which is not to be heated is covered with slack coal.

Short Link Chain.—*See* **Chains.**

Shovels.—Used by moulders for box filling and sand mixing.

Shrinkage.—A term which is generally used as synonymous with contraction, to denote the diminution in bulk which occurs when a body cools down from the molten condition to atmospheric temperature. This occurs in all metals, excepting antimony and bismuth. Its amount varies considerably with different metals and alloys, and with the same under variable conditions of moulding and pouring. Coefficients of contraction are taken in the pattern shop and foundry in the practical form of a definite allowance added per foot in the construction of the pattern; and in the smithy per foot of forging. For convenience the former are embodied in the *contraction rule*, for iron and brass. But it is well understood that such a rule must be used with judgment, and the allowances for shrinkage increased or lessened in certain jobs.

It has been proposed to make a fine distinction between the terms shrinkage, and contraction, retaining the first to signify the cooling down from the molten to the solidified state, and the second to denote the cooling which goes on from solidification to the cold state. Except, however, as a convenient distinction for the purpose of assisting the study of certain phenomena which are associated with shrinkage it has no practical value. All the workman wants to know is as exactly as possible the difference in dimensions of a casting (or forging) when made, and when cold.

The phenomena of shrinkage is easily demonstrable in two or three ways. If an open mould is poured, the metal can be seen visibly shrinking away from the sand at the edges as the cooling proceeds. If a closed mould is opened by lifting the top, without disturbing or breaking the sand in the bottom, an open space of $\frac{1}{8}$ in. or more is seen in a fair sized casting between the edges of the casting and mould. If a rather massive mould is poured, and not fed with fresh metal to compensate for shrinkage, the top of the casting will be found depressed, or else there will be a big draw or open space somewhere in the casting where the heaviest body of metal is massed. If a portion of a long casting is tied by something which will not allow the casting to shrink, then fracture will occur. This may be a hard mass of core in the casting itself, or a bar or stay in the moulding box. If the length of a pattern is compared with that of the casting moulded therefrom, the latter will be found shorter than its pattern.

Speaking of a casting being tied in such a way that shrinkage is prevented, opens up a very wide set of conditions which are ever present in the foundry. We said that the contraction rule must not be relied on absolutely. That is, one casting, say in iron will shrink more or less than another casting poured from precisely the same metal. Sometimes this difference in shrinkage is not necessarily absolute. We may concede that the metal if unfettered would shrink alike. It does not do so because it is in some way or another held in bondage, or else the mould does not retain its dimensions. The difference then does not lie in the metal, but in the mould. Yet it has to be taken into account, since the ultimate dimensions of the casting is the essential thing.

If a light square casting is cast around a centre of hard cores it will hardly shrink across the

at all. It will shrink a little more at ds, so that the sides will be convex when But if the metal is very light, the cast- ll certainly fracture. In such a case the are loosened and broken up before the g has proceeded far. A thin pipe of large ter would fracture around a hard loam In cases where there is no risk of fracture rinkage may be checked so much that will be little or no difference in the sions of the pattern and casting.

en a deep mould is cast, the shrinkage appears less than the proper amount. s caused by the *straining* of the mould, the hydrostatic pressure of the liquid There are ways of guarding against but the phenomena must be taken t of.

s, and temperature of metal exercise an ce on the shrinkage. A thin casting will ormally if its shrinkage is unobstructed. heavy one will not, one reason, outside f straining just mentioned, being that ter portions set firmly, while the interior s in a semi-molten state. The latter in is bound by the exterior, and the metal s on itself, or towards the outer portions y set. The result is an open crystallisa- the central areas, and in many cases cavities—*draws*—destitute of metal.

mould is poured with dead, or dull metal, rinkage will be less than as though hot were used. Different grades of metal different shrinkages. Thus chilling and irons shrink more than ordinary mixtures, on more than good mottled.

arent discrepancies often arise, not from rinkage being so erratic as it is believed but because the mould is not of the same s the pattern. In checking shrinkage re the mould is the thing to measure. ifference may be due to excessive rapping, mending up of broken parts, to the sweep- of portions of work, to bad jointing of loose pieces, grids, drawbacks, cores, &c. n what has been said it is obvious that stion of shrinkage is not one which affects uracy of dimensions only. That may be l matter when machining has to follow, nparison with the evils that result from excessive straining, due to the pull of some shrinking parts against others which are not able to accommodate themselves to the shrinkage stresses. If thick and thin parts are cast adjacent, and tied in such a way that the shrinkage of one is interfered with by that of the other, then the weaker parts will either become stressed, or bent, or broken, depending on conditions. This is the reason why careful proportioning has to be done in metals which are weak in tension, as cast iron, or which are highly contractile, like cast steel. It also explains why many castings would camber or curve in cooling if the pattern were not cambered the reverse way in the first place to counteract it.

Shrinkage Head. — Synonymous with **Head Metal**, and **Feeding**.

Shrinkage Hole.—A cavity in the central portions of a casting caused by the metal shrinking away from the centre in cooling. *See* **Shrinkage**.

Shrinking Fit, Shrinking on.—Relates to the practice of effecting a tight fit between a hole and a pin or centre, by taking advantage of the expansion and contraction of metal with varying temperatures. It is utilised in shrinking railway wheel tyres around their centres, crank webs round their pins, and shafts and cylinders on their liners, and many lesser used portions of mechanism. The heating may have to be done to a high temperature—a good red—as when the bore of a tyre has to be slid over a check on a centre In the case of crank webs, and cylinders, a slight warming suffices. Much care has to be exercised to avoid the sticking of pieces which are being shrunk on, before they have been adjusted to their exact positions. If that happens, heat has to be applied to the outer portion while the interior is kept cool. Old parts are sometimes separated in this way by a reversal of the process of shrinking on.

This method of fitting has given the term to suitable allowances to be made in such cases, termed *shrink fits*.

Shrink Rule.—A term sometimes applied to the patternmaker's **Contraction Rule**.

Shroud Laid Rope.—A common rope in which the strands are twisted or laid up in the

same direction, as distinguished from **Cable Laid Ropes**.

Shroud, Shrouding.—The flanging or capping of the ends of wheel teeth. There are two kinds of flanging, that to the points of the teeth—*full* shrouding, and that to the pitch lines—*half* shrouding, or *rolling* shrouding, because the edges of the pairs of wheels are in contact along the edges of the flanges. These edges are turned. Spurs and bevels are each treated thus. It is adopted in small and large wheels and pinions to strengthen the teeth.

Shunt.—A device or arrangement of electrical connections for diverting a portion of, or unequally dividing the current flowing in a circuit. Used as a noun, the word usually describes short pieces or strips of metal introduced in series with a main circuit, and being for equal lengths of comparatively high resistance to the main conductor to produce a slight fall of potential in its length. Having a comparatively long coil of very high resistance connected in parallel with itself, the main current at this point divides, the greater portion of it flowing on through the shunt strips, but a smaller part being diverted or "shunted" through the high resistance coil. This coil is wound round the armature of an ammeter, or other device, producing an effect therein which naturally and automatically varies with the current flowing in the main circuit.

The word shunt has many applications in electrical work, and these are explained wherever occurring, as in **Shunt Winding**, &c.

Shunt Winding.— This is used for dynamos which are required to supply constant pressure at varying loads, as for lighting and power circuits. For motors required to run at fixed or variable speeds continuously, irrespective of variations in their load, this system is necessary.

Thus, a motor required to steadily drive shafting,—which in its turn may drive numerous machines, any one or more of which may be started or stopped, loaded or unloaded, without affecting to an appreciable extent the speed of the others,—would have its fields excited by shunt windings.

Or, a motor driving independently a given machine wherein some parts of its operations require to be done at different speeds according to the size or character of the work, such as lathes, drilling and boring machines, pumps, &c., would also have shunt windings. Shunt windings with regulating rheostats give more exact and longer ranges of adjustment with more economical running of the motor than does regulation by control of the armature or main current by series regulation, and the motor will continue to run steadily at the predetermined speed whatever the load (within its proper range) may become.

Hence a **Series Winding** is used only where speed automatically varied to suit the work is required. *See also* **Dynamo**, &c.

Shut, Shutting.—The terms usually employed by smiths to denote a weld, and the making of the same.

Shutting Link.—A chain link which unites a piece of chain to a lifting hook or ring. It is made of iron about $\frac{1}{8}$ in. larger than that used in the chain, and the link is $\frac{1}{4}$ in. or $\frac{3}{8}$ in. larger. This is to ensure a margin of strength, and to facilitate the work of welding or shutting up.

Side Chisel.—The chisel of the wood turner. It is a double bevelled tool, and its edge lies at an angle with the chisel lengthwise. Its obtuse angle is presented when turning, the chisel being held on the rest with its cutting edge at a tangent to the revolving work. Only a portion of the edge is in operation, say from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. away from the corner. The handle is gripped firmly by the right hand, and the cutting edge manipulated with the left. When the tool is used for cutting downwards in a direction approximating to the perpendicular, or for cutting off, the acute-angled end is presented. Then the keen corner only, and not any sensible length of cutting edge is in operation. This is a true cutting tool, capable of producing a very clean face. Firmer chisels are used also, but only as scrapes.

Side Elevation.—A view taken against the perpendicular face of the side which corresponds with the longer dimension of an object.

Side Frames, or **Side Cheeks.**—The main frames by which the mechanism of cranes is supported. Various shafts pass through

bearings in the frames to carry the gear wheels and drums. The frames and gears form the superstructure, as distinguished from the bed, truck, or foundation, as the case may be. They are made of cast iron, or steel-plated, or built up of plain rolled sections.

Side Hooks.—The coupling hooks of railway wagons which flank the draw hook.

Side Lever Engine.—A type of paddle engine nearly universally adopted in the earlier years of steam navigation until supplanted by the oscillating cylinder engine. The last engines of this kind in the Atlantic service were fitted in the *Scotia*, 1862. It might be considered as essentially an inverted beam engine, the side levers being identical with beams. The cylinders were set vertically on the base plate. The piston rod was connected by a crosshead above to two side rods outside the cylinders. The opposite ends of the side rods were pivoted to one end of the beams, the other ends of the beams being pivoted to the connecting rods, whence the cranks rotated the paddle shaft. The design had the merit of keeping the heavy parts low down in the hull.

Side Planing Machines.—These are characterised by a travelling tool arm which moves over the work attached to a table or tables at the side of the machine. The moving mass is limited to the arm and its fittings, and is uniform alike for heavy and light work. There is no limit to the width of the work which can be operated on, as there is in the housing design of machines, or even in the open-side machines in which one housing is omitted, or is removable, but in which the work is still carried on a table underneath a fixed tool arm. There is a limit to the width that can be tooled, due to the elasticity of the tool arm, but that is often less serious than the limit to width of work imposed by the common machines. About 60 in. is the widest available breadth which can be covered by the largest side planers. A great

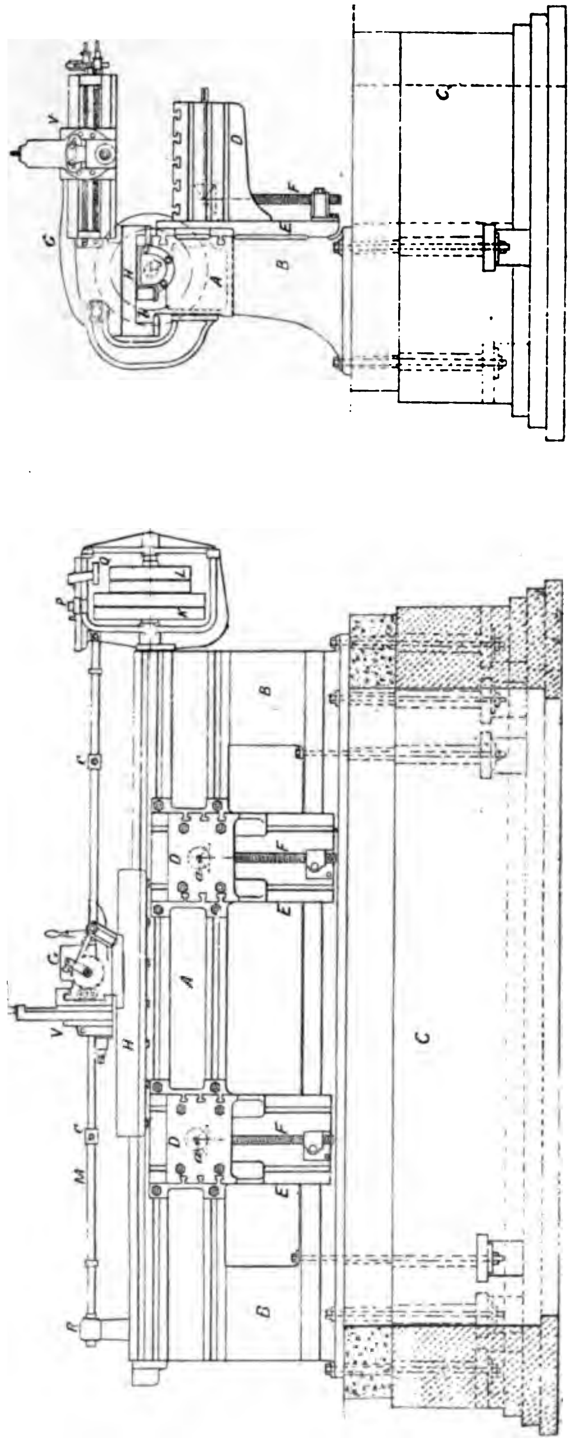


Fig. 179.—Side Planing Machine. Front and End Elevation. (Geo. Richards & Co., Ltd.)

length is available, and these machines will plane from 2 ft. to 30 ft. in length, with the advantage that the length of shop room required is only half that of the common planer in which the table has to run to and fro. There is far less mass to be carried and reversed, and the reversing shafts and wheels are dispensed with. These, with some lesser advantages which will be obvious on a study of this machine type, sufficiently explain the great popularity which it has achieved.

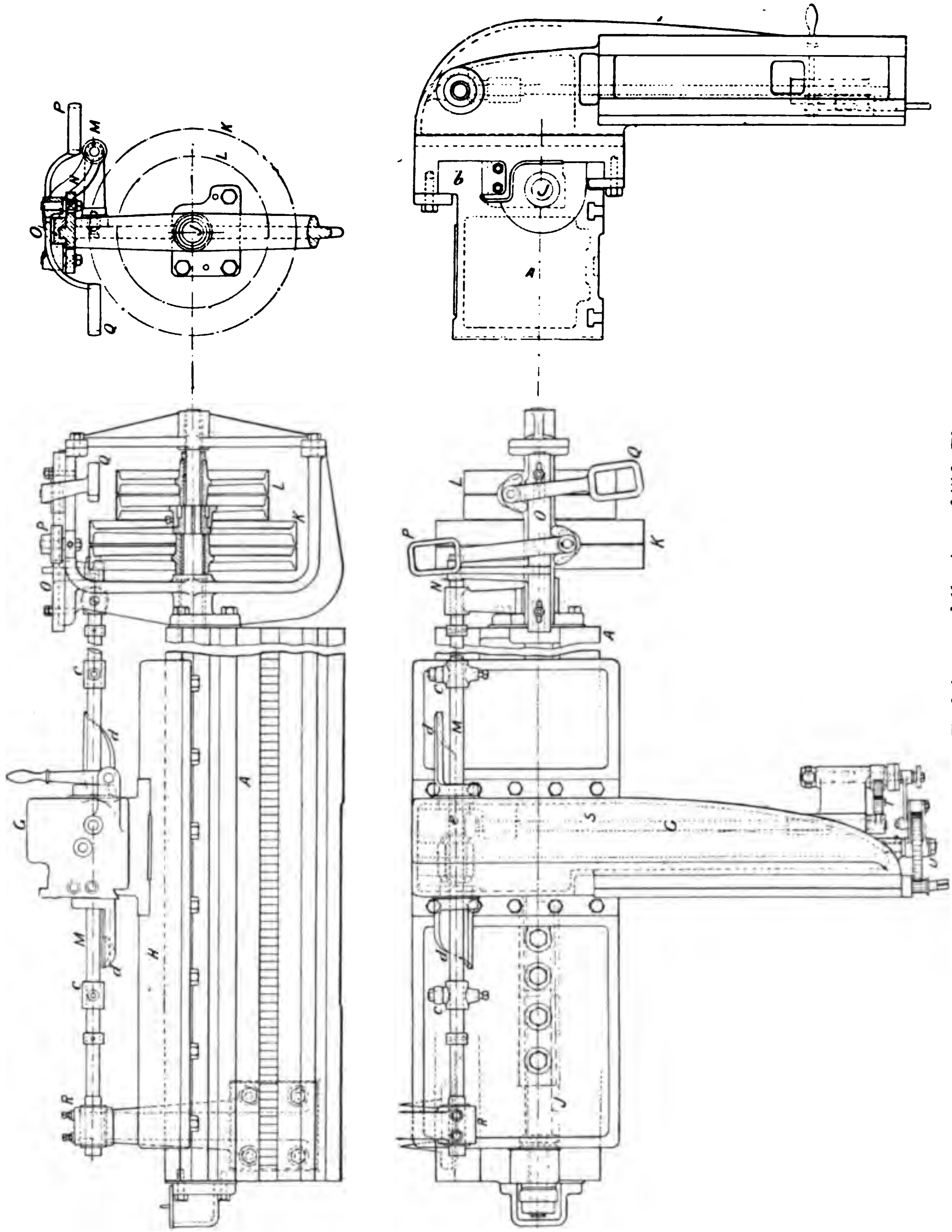


Fig. 180.—Tool Arm, and Carriage of Side Planer.

The Figs. 179 to 185 illustrate a machine

to plane up to 6 ft. long by 20 in. wide. It is one of medium dimensions, and is built with a bed carried on feet. The smaller machines are of box bed pattern, reaching to the ground with a spreading base.

In Fig. 179 the bed A is carried on two feet B B bolted down to a suitable foundation, with a pit, C, in front enclosed with masonry. The value of the pit is very great in taking work which is too deep to be got in between the tool and the floor. Two knee work tables, D D, are adjustable vertically on saddles E E, which are adjustable along the bed face. Both tables and carriages fit by strips in grooves, and are secured by tee-head bolts. The vertical movement of the tables, effected by a handle at the front at *a*, through bevel wheels, and a screw F, is essential for adjustment of the height of work, since the tool arm remains at a constant height. The tables have tee grooves at the sides as well as on top, since it is often convenient or necessary to bolt large pieces at the sides.

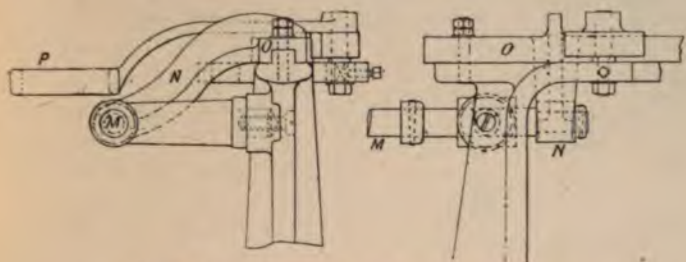


Fig. 181.—Enlarged View of Striking Gear.

The driving arm G with its sliding carriage, or saddle, Fig. 180, H, are features of interest. As the overhang of the arm would be a source of tremor, and of torsional effect, precautions are taken to prevent or minimise these evils. The carriage is longer than the arm which is attached to it. Also, instead of being guided by edges at front and back, the guidance takes place on the back shear *b* only, and the width of the guiding member *b* compared with the length of the carriage is as one to eleven. This, with the gibbing, is seen in Figs. 179 and 180.

The carriage is traversed and reversed by a double-threaded screw J, Fig. 180, from the pulleys K and L respectively. The cutting speed may be as high as 40 ft. per minute, and the return 100 ft. The two fast pulleys, seen in section in Fig. 180, are adjacent to each other, flanked by the loose pulleys on the outside. The screw shaft and pulleys are well supported by a bracket, and bridge piece. The striking gear is actuated from the rod M, on which are the adjustable dogs *c*, *c*, which are struck by horns *d*, *d* on the side of the tool arm. The rod M moves the arm N and slide bar O, which actuates the belt forks P and Q. These are shown enlarged in Fig. 181.

The striking bar M is also made to impart the down, and cross-feed to the tool box, thus. In the left-hand bearing R, which carries the bar M, a bush encircling the bar has two cam grooves, Fig. 182, into which studs that pass through the bar enter. The effect is, in combination with the action of the horns *d*, *d*,

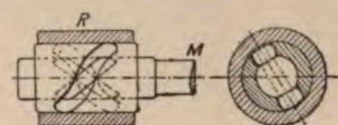


Fig. 182.—Cams for Imparting Down-feed.

to give a twist or partial rotation to the bar through an angle of 120°. These horns it will be noted have spiral edges, and they thrust against rollers on the stops *c*, *c*, so working nearly frictionless.

The arc movement of the rod M is transmitted to the feed through mitre gears *e*, and shaft S, to segmental gears T, at the end of the tool arm, Fig. 180, also shown enlarged in Figs. 183, 184. A ratchet feed U, Fig. 180, is actuated therefrom, whence gears operate the feed screw for cross traverse of the tool box V, Fig. 179, and the splined rod W, for the down-feed, Fig. 185. The details of the tool box are clearly seen in this figure. Compare

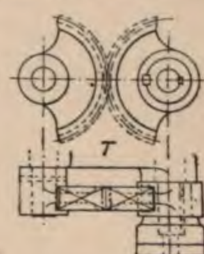


Fig. 183.—Segmental Gears.

with the enlarged details of the ratchet feed, Fig. 184.

The ratchet gear, Fig. 184, shows the segmental gears T, which give a partial rotation to the crank disc *e*; this disc has a sliding nut and pin, which can be adjusted across the slot, and clamped by a knurled wheel. The lever *f*

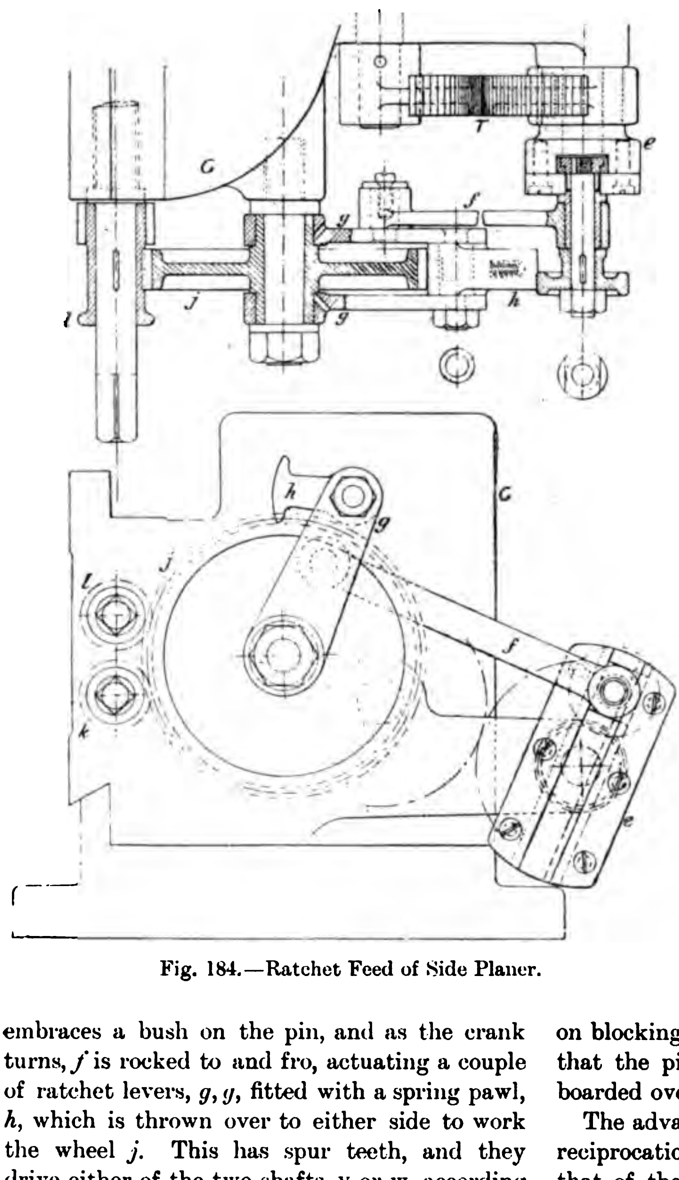


Fig. 184.—Ratchet Feed of Side Planer.

embraces a bush on the pin, and as the crank turns, *f* is rocked to and fro, actuating a couple of ratchet levers, *g*, *g*, fitted with a spring pawl, *h*, which is thrown over to either side to work the wheel *j*. This has spur teeth, and they drive either of the two shafts, V or W, according to which of the sliding pinions *k* or *l* is slid into gear.

The tool box, Fig. 185, is gibbed to the arm G, and comprises a saddle, *m*, having a swivelling plate, *n*, secured with bolts sliding in vee-grooves. A long slide, *o*, is moved up and down on the vee-ways of *n* by the screw *p*, and it carries the plate and clapper tool holder *q*, which may be angled upon *o* and secured by two bolts. The tool is gripped by the end of the single set-screw. The movements are obtained, first across the rail by the screw V, already mentioned, working in a nut screwed to the back of *m*, and the up and down motion by turning the screw *p* from its squared end. The automatic feed, derived from the splined shaft W takes place through mitre gears, *r*, the intermediate pair being passed through the body of *m*, and are united by a screw and dowels as seen in the separate detail to the left. The last gear encircles the screw *p* loosely, and rotates it by means of a key entering into the spline running longitudinally through the threads. There is a differential arrangement where *p* enters *n*, to take up slackness; a nut or gland threaded externally with a thread of finer pitch than that of the screw, is turned in a little as required, and locked with a nut.

Fig. 186, Plate XIV., shows a side planer operating transversely on a bed for an air compressor. This, as will be seen, would be too long to go between the uprights of an average planer, but it is tooled with ease on the side planer, resting on the table of the machine at the one end, and on blocking at the outer end. It may be noted that the pit in front of the planer is partly boarded over when not in use.

The advantage of the side planer, due to the reciprocation of the light tool arm in place of that of the massive table and work is seen in the tooling of isolated facings on large areas. Instead of going across these, and cutting wind

Fig. 176.—150-Ton Hammer Crane. (Sir William Arrol & Co., Ltd.)

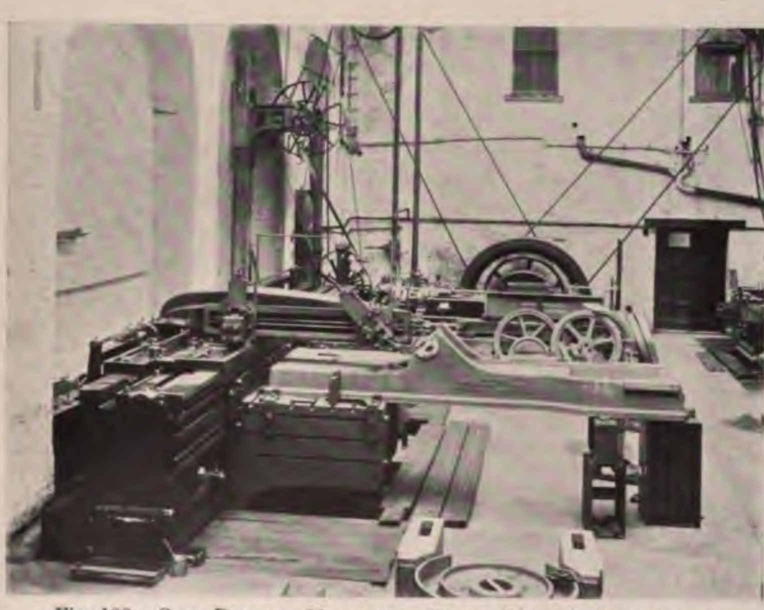
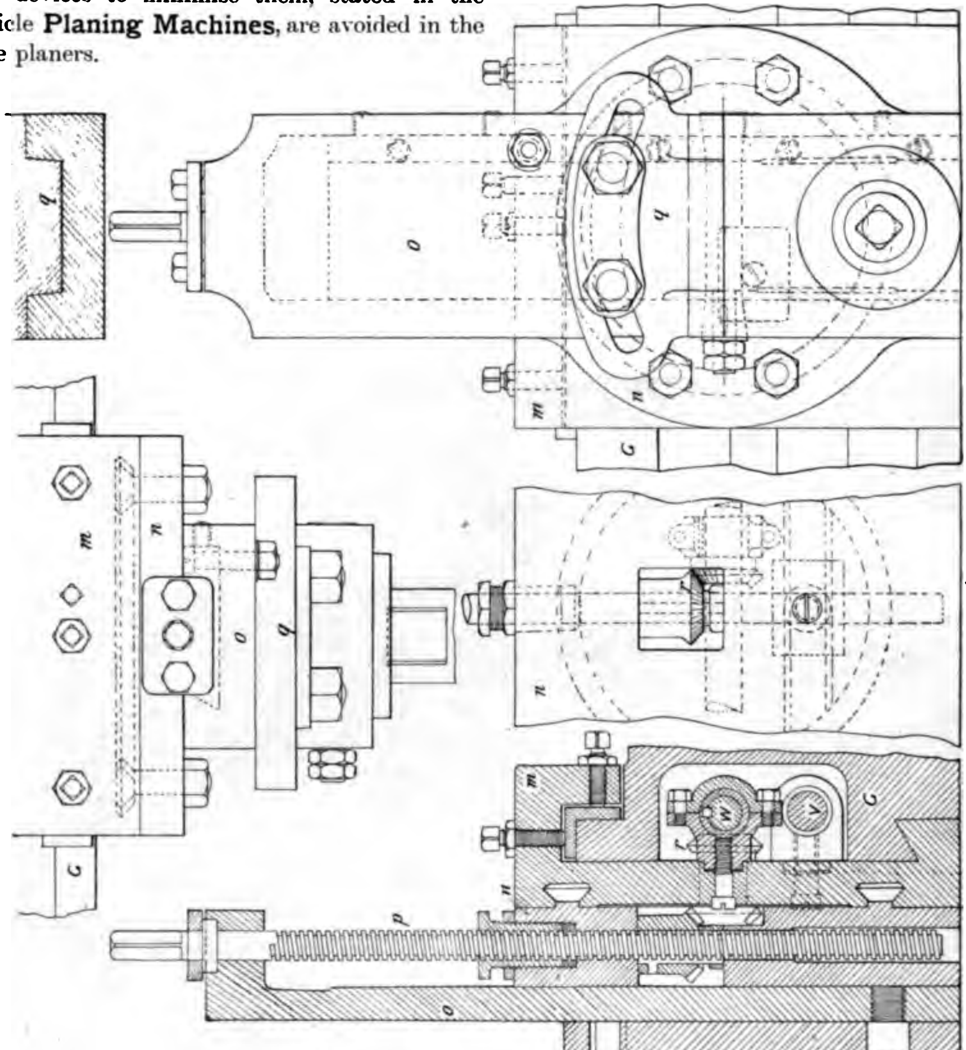


Fig. 186.—Side Planing Machine. (George Richards & Co., Ltd.)

To face page 170.

in the spaces, each facing is tooled separately. All the disadvantages of a moving table, and the devices to minimise them, stated in the article **Planing Machines**, are avoided in the side planers.



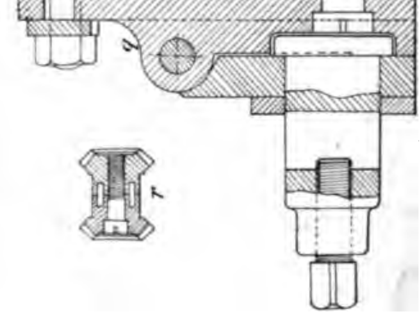


Fig. 185.—Tool Box for Side Planer.

An advantage of having two work tables available is, in addition to the fact that long pieces can be carried thus, that a short article can be tooled on one, while another piece is being fixed on the other table.

Comparison is sometimes made between the shaper and the side planer. There is a similarity, but the advantages are in favour of the latter. The shaper arm becomes less rigid, receiving less support as it moves outwards, while through a single cut the planer arm remains in the same position of overhang. And whereas there are two sets of sliding surfaces in the shaper, there is only one in the planer.

Side Tool.—A chisel like tool used as a scrape by wood and metal turners for operating on surfaces which lie with more or less approximation to the axis of the lathe. It is a *right-hand*, or a *left-hand* side tool, signifying that the bevel of the edge turns a right, or left handed surface respectively. Or a tool may combine both angles, in which case it is termed a diamond point. The slope of the edges of these tools may range from 30° to 60° with the shank. The greater the slope the deeper can they penetrate in narrow spaces.

Siemens Process.—The process of making **Open-Hearth Steel** by the removal of carbon and silicon from pig, using iron ore as the oxidising agent. In the Martin method, steel scrap was first used without ore, the scrap being dissolved in a bath of molten pig. At present pig, ore, and scrap are used, so that the difference between the Siemens and Martin processes has ceased to have any practical importance.

Sieve.—The sieve is used in foundries for the purpose of sifting sand over moulds and patterns. The facing sands are sifted over thus, but for mere box filling the shovel is used. A *riddle* is a sieve, but it is usual to distinguish between the two, the sieve having finer meshes, which range from eight holes per lineal inch downwards, and the riddle from 1-in. down to $\frac{1}{8}$-in. meshes. Eighteen mesh is the finest sieve made for ordinary ironfounders' use, but for parting sand for brass work, meshes as fine as twenty-six are used. Riddles and sieves range from 14 in. to 20 in. diameter. They are made with iron wire, galvanised iron wire, and brass wire.

Sight Feed Lubricator.—*See* **Lubricators.**

Sight Holes.—Holes in the sides of furnaces through which the process of melting down can be watched. They occur in cupolas, where they are covered with mica, and in hot blast stoves, and gas producers.

Silent Feed.—A class of feeding mechanism used largely on frame saws, to impart the forward motion to the timber. The up and down movement of the frame works a rocking lever, pivoted around the axis of a wheel, having a vee-shaped groove on its periphery. A cam block, or smooth pawl on the rocking lever engages with the vee-groove, jamming itself on the forward movement and so turning the wheel, which in turn operates the gears driving the feed rollers, or the racking pinions, as the case may be. By throwing the pawl backwards the feed can be instantly arrested.

Silica Bricks.—Fire-bricks used for the linings of open-hearth furnaces. They are employed for the portions where the heat is most intense, as the roofs and ports. The best bricks are made from the Dinas rock of South Wales. They contain from about 97 to 98 per cent. of pure silica, about 1 per cent. of alumina, and small quantities of ferric oxide and alkalies. The bricks are made with from about 1 to 2 per cent. of lime added as a binding material, in the form of a thin paste mixed with water, added during the crushing of the rock, which is done coarsely in rolls. The bricks are shaped in moulds, are then partly dried by steam, and subsequently burnt while stacked in kilns for about five days. After being allowed to cool down they are removed. They expand about $\frac{1}{4}$ in. in 9 in. in burning. They are set in a paste of silica cement and water. These bricks, though suitable for roofs, are not used for hearths and linings which are exposed to the action of metallic oxides. Bricks containing a large percentage of alumina are used for these localities.

Siliceous Sands.—Sands which contain maximum proportions of silica, ranging as high as 98 and 99 per cent. They are used largely in the manufacture of fire-bricks, and as mortars or cements in setting fire-bricks in the pig beds of blast furnaces. They are used by iron and steel founders. *See also* **Sands.**

Silicon.—Si, 28·4; sp. gr., 2·4; melting point, 1200°; specific heat, ·17. With the exception of oxygen there is no more abundant element than silicon. It is not, however, found in the free state, but in combination with oxygen, forming silica, SiO_2. Flint, quartz, and sand are examples of silica in an almost pure state. Glass is a combination of silica with one or more basic substances. Clay, mica, pumice stone and slate are aluminic silicates; asbestos and talc are magnesic silicates. In combination with oxygen and a metal, silicon forms a metallic silicate. As shown under **Slags,**

on forms 30 per cent. of an average slag the blast furnace.

eing highly infusible, silica, in combination alumina, is an important constituent of fire- and other materials used in furnace con- ction. The following are the percentages lica in these materials :—*Firebrick:* Stour- ge 73, Newcastle 73, Flintshire 88, Leeds 77, sher 65; *Ganister bricks:* Lowood 96, ton 94; *Dinas bricks:* 96; *burnt dolomite* 6. mina forms the largest proportion of re- ning constituents, and ferric oxide, lime, nesia, potash and soda are present in traces. hardening of Portland cement has been d to be due to the presence of tricalcium ate, $3CaO.SiO_2$.

licon is of immense importance to metal- ists in iron and steel. Its effects on **Cast n** are treated under that head, and under **ep's Tests**. Remarks on silicon will be d under **Bessemer Steel** and other ls.

ilky.—Denotes a particular aspect of tured surfaces in iron and steel, being the osite of granular. When a specimen is asunder slowly, the ruptured surfaces will, good tough material show a well marked ly fibrous aspect, as though the metal were posed of bundles of threads of glossy erial. Inferior metal will approach more the crystalline aspect, while intermediate ities will manifest both aspects. It must borne in mind that the silky fibre only ears when the rupture is gradual. The e bar, which, torn asunder slowly will be y in character, will if ruptured instantly v crystalline surfaces.

ilver.—Ag 107·13; sp. gr., 10·5; weight b. per cubic foot, 654; weight in lb. per ic inch, ·377; modulus of elasticity in lb., 00,000; specific heat, ·0557; melting point, 9-1873° Fahr.; coefficient of expansion by , ·00001055; latent heat of fusion, 38·0.

ilver is found native, and combined with hur, antimony, chlorine, and bromine. ena, the principal ore of lead, contains es of silver in sufficient quantities to rantee profitable extraction. The lead is jected to the operation of cupellation, *i.e.*, s oxidised in a reverberatory furnace on a bed of bone ash, a blast of air being blown across it during the operation. Owing to the affinity which mercury possesses for silver, the process of amalgamation is also employed with some ores, the mercury being afterwards driven off by distillation.

The ore is roasted with common salt to form silver chloride, and crushed in stamp batteries, water being admitted. The ore mud is next placed in settling pits, and eventually placed in amalgamating pans. Here the ore is pressed to a pulp, mercury is added and an amalgam formed from which the mercury is driven off by distillation.

Silver is extremely ductile and malleable, and is a better conductor of heat and electricity than any other metal. It is insoluble in hydrochloric acid, but readily dissolves in nitric acid or hot sulphuric acid.

Electro-plating is the process of depositing silver on the surface of some baser metal. The object is placed in a solution of cyanide of silver in cyanide of potassium. The current from the battery decomposes the cyanide of silver, and deposits the metal on the suspended object.

Simple Train.—A pair of gears comprising one pinion and one wheel only. A compound train comprises two or more pairs. *See* **Screw Cutting**.

Simpson's Rule.—This is a method of finding the approximate area of irregular figures (Fig. 187), to which the ordinary rules for finding the area cannot be applied. The method is illustrated in the first of the three figures. A number of straight lines are drawn at equal distances apart as shown, at right angles to AB, and meeting the curve. These lines are called ordinates, and the greater the number drawn, the more accurate will the result be. Having found their lengths and the common distance between ordinate and ordinate, the rule is :— Add together the first ordinate, the last ordinate, twice the sum of all the other odd ordinates, and four times the sum of all the even ordinates; multiply the result by one-third of the common distance between two adjacent ordinates. In the figure the odd ordinates are, e, g, i, k, m; the even ordinates are f, h, j, l. As an example, suppose the ordinates in this figure to measure 1, 1·2, 1·3, 1·4, 1·5, 1·4, 1·3, 1·2, 1 foot respec-

tively, and the common distance between the ordinates to be 9 inches or ·75 foot. Then according to the rule:—

1	1·3	1·2	2·0
1	1·5	1·4	8·2
—	1·3	1·4	20·8
2	—	1·2	—
	4·1	—	31·0
	2	5·2	·75
	—	4	—
	8·2	—	1550
		20·8	2170
			—
			3)23·250
			7·75

The approximate area is thus $7\frac{3}{4}$ feet.

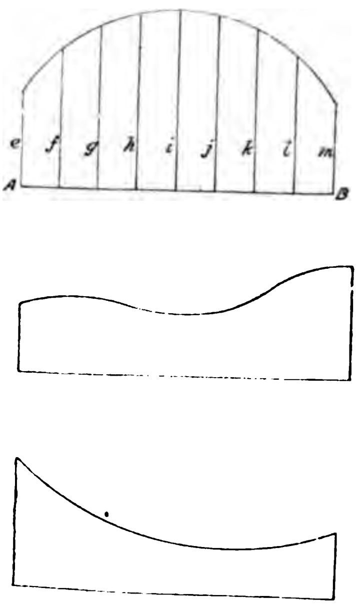


Fig. 187.—Simpson's Rule.

This is obviously a useful rule for engineers, and though it reads somewhat clumsy, may be crystallised into a simple formula if we denote the ordinates by a_1, a_2, a_3, a_4, a_5, &c., and the common distance by h. Then, area $= \frac{h}{3}(a_1 + 4a_2 + 2a_3 + 4a_4 + 2a_5 + 4a_6 + 2a_7 + 4a_8 + a_9)$. That is, the first ordinate is multiplied by 1 (*i.e.*, unaltered), and all succeeding ones by 2 and 4 alternately, except the last which is also multiplied by 1. The total is multiplied by one-third of the common interval.

Single Belting.—*See* **Belting.**

Single Butt Strap. Single Riveting.—*See* **Riveting.**

Single Curve Teeth. — Understood to signify the involute form of tooth, although there are other single curve teeth possible.

Single Cut File.—*See* **Files.**

Single Ended Boiler.—A boiler fired from one end only. Usually restricted to designs of the **Scotch Boiler.**

Single Gear.—The engagement of one pinion with one wheel. Often used incorrectly to signify a drive in which no gear is used, as the direct belt drive of a lathe, to distinguish it from the back gear drive or double gear.

Single Phase Motor.—An alternating current motor suitable for use on single phase circuits. Such motors will only operate so long as their phase is in step with the alternator, hence if overloaded they stop and cannot be started until unloaded. *See* **Induction Motor.**

Single Purchase.—The power gained by one pair of gears, or levers.

Single Rail Cranes, or **Walking Cranes.**—These have been long used in machine shops, and to a lesser extent in fitting and erecting shops, alternative to overhead cranes, and in cases where countershaft or roof arrangements are not adaptable to the use of overhead runways. Overhead tracks are, however, being used extensively in cases where single rail cranes would have been laid down a few years since. The machine shops of the Manchester district and the North of England and Scotland are, however, still largely equipped with the single rail crane, which is an excellent design. It occupies no room save that of the particular location in which it happens to be standing, or to be in service for the time being. The single rail below, flush with the floor, and the pulley above which runs between the joists or beams interfere with nothing. The jib slews to serve machines or benches to right and left. The crane can be designed for operation by hand, or cotton rope, or electricity. Powers usually range between about 1 ton to 5 tons.

The general design of all these cranes includes an under-carriage which carries the bearings

for two wheels, one at front and one at rear, to run along the rail in the floor. The carriage may be a hollow casting in the smallest cranes, but it is built up of plate and angle in other sizes. Or channels or plated sides may be connected with cast distance pieces. A post is stepped into the carriage, and extends to the guide rails overhead, within which it is steadied with horizontal rollers carried in a pair of bars. Around the post the jib revolves. In all but the smallest cranes the jib does not slew directly round the post, but forms a portion of two crane sides which flank the post, and run round it on horizontal rollers. The tie rods coming from the head of the jib are attached to these sides. They are formed of plain rolled channels, or are built of plate and angle to the channel section. The jib is rigid, derricking motion not being necessary, since the radius can be regulated to any distance by slewing, up to the position at right angles. For slewing, the crane is simply pulled round by hand.

Hand Cranes.—In these a rope or chain dependent from a spider wheel is used to actuate a spur pinion and wheel. The spider wheel is on the pinion shaft, and the wheel is on the barrel shaft round which the lifting chain is wound, going thence to the pulley at the end of the jib. The gears are fixed on the end of the jib close to the post. The travelling is done by hand gear carried at one end of the under-carriage.

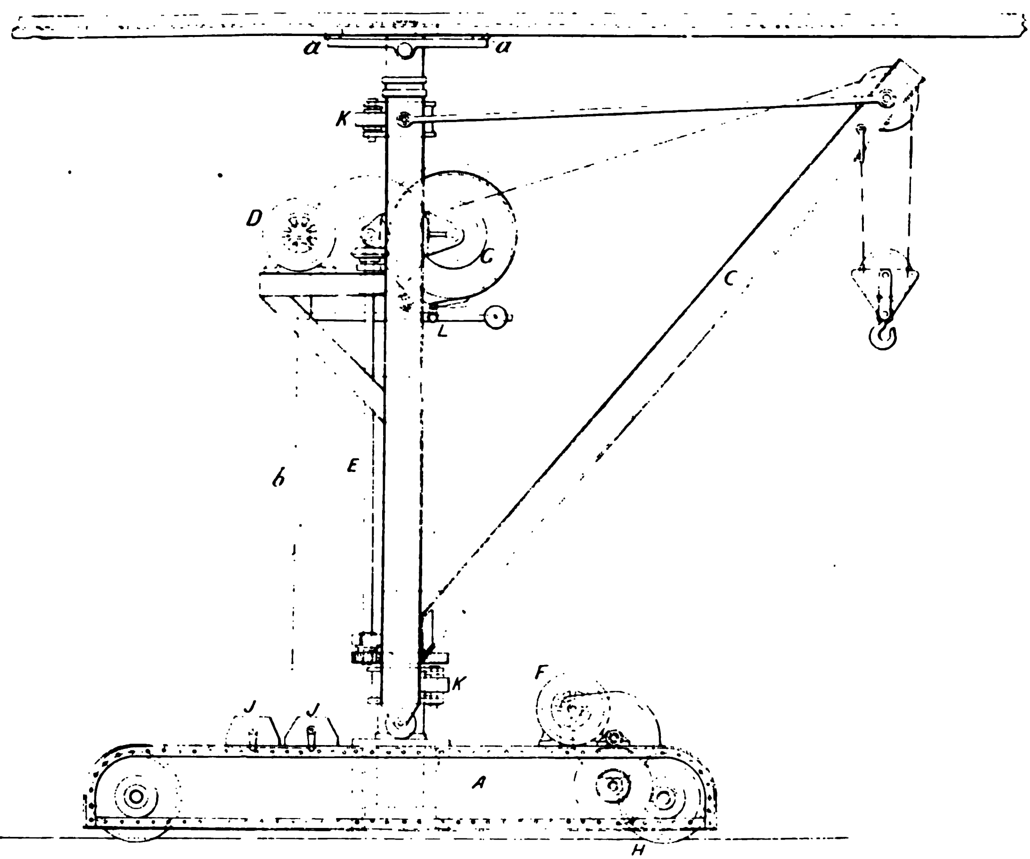


Fig. 188. –Single Rail Crane.

Cotton Rope Cranes.—In these a high speed cotton rope, running along the shop, drives a pulley flanked with guide pulleys at the top of the crane, keyed on a vertical shaft alongside

the post. From this shaft both the lifting and travelling motions are actuated by the attendant alongside. Slewing is done by hand.

Electric Cranes.—These, in new installations, would be fitted in preference to hand or cotton rope drives. The lifting and the travelling are each done by separate motors. The speeds are double those which are available with cotton rope drives. Slewing is done by power in some of the heavier cranes.

Fig. 188 illustrates a 5-ton single rail electric crane by Messrs Joseph Booth & Bros., Ltd. The under-carriage A is of box form, built with plate and angle. The sides are of rolled joists, as is also the jib C. The hoisting motor D is carried on a bracket platform. It also slews by bevel gears, driving to a vertical shaft, E, with spur gears. The travelling motor F is placed on the under-carriage. Each drives through a train of spur gears outlined, the first to the hoisting drum G, the second to the travelling wheel H. Worm reduction is used in some cases. Current is taken from copper wires carried along overhead. J J are the controllers. The pull of the jib forwards is resisted by the rollers K K at back and front of the post. The top guide rollers are seen at *a a*. L is the brake, put on by the cord *b*.

Singles.—Sheets which have been rolled singly without doubling. *See* **Sheets.**

Single Shear.—A rivet or pin is in single shear when the action takes place in one section only.

Single Webbed Girder.—A girder with one central web only connecting the flanges.

Sinking Pumps.—Special pumps employed for clearing the water from mines, shafts, and foundations. They are driven by steam or electricity, and are suspended from chains by which they are lowered. The conditions of service are severe, and such pumps are therefore constructed strongly, and with as few projecting parts as possible. In the steam-driven types, the cylinders are placed in line, and the steam inlet and exhaust are controlled by internal valves actuated by tappet or other gear. In electric pumps the motor is usually mounted on the top of the frame, and it drives by a double reduction gear to a crankshaft, actuating the rods and plungers of the pumping cylinders. Treble ram pumps are used for very heavy duty; they deliver a constant throw, and the power required remains equal at all parts of the stroke.

Pumps of the Pulsometer type are used largely for sinking purposes, being well suited for handling sandy or muddy water. In the case of deep shafts, it is usual to fix an upper pump, with its suction pipe drawing from a small tank fixed part of the way up the shaft, and use another pump to feed into this tank, the latter pump being lowered as the bore proceeds.

Skelp.—Strips of iron or steel prepared for making lap welded tubes. The rolled flat strip is bevelled on both edges with tools in a draw bench. The bevelled edges are bent up towards each other with a **U** section, and the strip is then raised to a welding heat, and passed between grooved welding rolls, and over a mandrel. This operation may be repeated, after which the tubes are straightened in a reeling machine.

Sketch Paper.—Foolscap paper which is ruled with faint crossing lines leaving small squares of uniform sizes. It is valuable in making hand sketches, because approximate proportions can be ensured without direct measurement.

Sketches—Sketch Plates.—Ship, bridge, and tank plates which are not rectangular. Plates which are radial, or sheared to templet, and circular plates are regarded as sketches. But it is usual to make an exception in favour of ship plates which have less than 9 in. of taper in a straight line. The extra for sketch plates is from 20s. to 25s. per ton.

Skewers.—Lengths of common wire from $\frac{1}{16}$ in. to $\frac{3}{16}$ in. diameter, pointed at one end and formed with a loop at the other, and used for retaining **Loose Pieces** in position during ramming. Long loose nails are often used as alternatives, but they have to be withdrawn with pincers, while skewers can be pulled out with the fingers.

Skew Bevel Gears.—These are also called hyperboloidal gears. Their peculiarity is that their axes cross without intersecting each other. They are related to the spiral gears. The wheels are frusta of hyperboloids generated by

the revolution of a straight line about an axis with which it is not parallel. Their design involves a great deal of mathematics and they are seldom employed, spiral gears being used in preference. It is practically impossible to get the shape of the teeth correctly, apart from a moulding process. There is a particular form of the skew bevel gear which has been used to a limited extent, in which the axis of the pinion does not intersect that of the wheel, but lies parallel with it. The only way to get the shape of the teeth in this case is to make those of the pinion first, involute or cycloidal, and cut the wheel teeth to suit. In any of these gears the friction of the teeth is excessive, because sliding action predominates.

Skid.—An appliance used in steel works for conveying blooms and slabs from roughing to finishing rolls. It comprises a series of runners arranged parallel with, and between the live rollers of the mill train, and moved back and forth in front of the rolls by an endless chain or rope, and all operated simultaneously from a shaft at right angles with the rollers. A tappet standing up from each runner above the roller bed, when brought against the edge of the bloom, moves it along laterally. A wheel is said to skid when it slips on its rail.

Skimming.—Preventing the slag and scoriæ which accumulates on the surface of a ladle of metal from running with the metal into the mould. It is done by holding a flat iron bar across the mouth of the ladle, and thrusting the scum back away from the mouth. The term *skimmer* applies to the bar, and to the boy who uses it.

Skin.—Signifies the outermost film of metal of a casting or forging. It is harder than the interior metal, due to the presence of oxide, and to the chill which occurs in contact with moulds in cast work, and with tools in forgings. The skin dulls the edges of cutting tools rapidly, which is the reason why a careful workman tries to "get below the skin" when roughing down, so cutting into the softer metal at once. This requires sufficient machining allowance to permit of doing so, hence it is often desirable in hard castings and large forgings to allow ample stuff to come off, rather than attempt to cut it finely. In small work where allowances are fine, pickling is resorted to in order to dissolve the scale, and leave the metal soft enough for tooling. One advantage of grinding is that the skin may be ground off as readily as the softer metal.

On the other hand there are many cases in which a hard skin is desirable. It was an argument in favour of cast gears that they wore longer than those in which the teeth were cut. The treads of cast trolley wheels were preferred rough to turned. But the required hardness is better secured by employing harder and tougher metal, and by the practice of **Chilling**. These devices are adopted in many portions of machinery where durability is essential. The same result is obtained in forged work by **Case Hardening**.

Skin Drying.—The practice of imparting a slight degree of hardness to the surface of a green sand mould previous to closing and casting. The mould is first brushed with liquid black wash, which, when dried, hardens, and binds the surface sand together. The object in view is to produce a clean smooth surface on the casting. This is in no sense a dried sand mould, which is of a different composition, and is dried throughout. For skin drying, portable devils are suspended over, or lowered into the moulds, or heaters simply, if moulds are of small dimensions. Moulds of dry sand are put into the stove bodily, or are dried *in situ* by currents of hot air.

Skips.—Buckets or boxes of iron or steel, or sometimes wood, used for carrying loose materials, and slung up by a crane. Contractors and builders make extensive use of skips. The simplest kind resemble a conical bucket suspended by a loop, the points of connection of which are set low down the sides of the skip; a forked dog is attached to the rim of the skip, and it embraces the loop there. When this dog is knocked upwards, the tip overturns and discharges its contents. The drop-bottom skip is another variety which discharges without overturning. A pair of doors are hinged at the bottom, and to fall open downwards on slackening a chain passing up from them, so that the contents drop in a straight line, exactly on the spot required.

Slab.—A mass of iron or steel, of rectangular

section, which has been reduced by hammering, or cogging, from puddled ball or ingot to dimensions suitable for rolling to a finished shape. It measures less in thickness than in breadth, differing thus from a bloom, which is of square section. Slabs are used for rolling plates and joists, and similar articles which are wider than they are deep.

A slab also denotes the outer flitches which are sawn from timber balks, to leave cleaner faces for the boards.

Slabbing Machines.—A synonym for **Plano-Milling Machines**, in allusion to their capacity for tooling large plain surfaces with heavy cuts.

Slabbing Mill.—The rolls in which ingots are reduced to slabs. They are a particular form of the **Cogging Rolls**, suitable for the slab sections, which are of greater width than thickness. A central pass, broad and shallow, is flanked by two passes relatively deep and narrow, which are used for the correction of the edges of the slabs.

Slack.—Signifies an easy or free fit between parts, generally in the sense of being too easy. Also the free portion of a chain or rope dependent from pulley blocks. Small coal and breeze are termed slack.

Slagging.—Causing the slag to run out of a cupola at intervals during the running down of the metal. The more white the iron, or the more oxide there is mixed with it, the more frequently must slagging be done. Good grey iron requires but little slagging. A hole is provided for this just above the breast hole, and a little below the level of the tuyeres.

Slags.—Anhydrous silicates of lime, alumina, manganese, magnesia, and of iron, yielded in the iron and steel producing, and melting furnaces, or with other metallic bases in the case of other metals. The slag is produced from the infusible silicious, calcareous, and other matters, termed the *gangue* of the ore, by the addition of a flux to the charge. Without the flux, large quantities of ore could not be smelted properly. Either portions of the gangue would remain with the reduced metal, or if separated the cost of smelting would be too great.

The colours of slags are due to the metallic silicates. The general colour, light or dark, the opacity or the glassy appearance, the fusibility, are affected by various causes, as a light or heavy burden, the rate of cooling, the presence of certain oxides. A slag is lighter than the metal, and floats on the surface. It is tapped out from the furnace at intervals.

In adding a flux to a charge to yield a slag, the flux must be selected with reference to the particular nature of the gangue. Thus every different class of ore requires difference in treatment. In a few cases iron ores contain enough calcareous material to be self-fluxing. Sometimes the slag is yielded by the admixture of two classes of ores, as silicious and calcareous kinds. When this can be done, it is preferable to adding foreign non-metallic fluxes, because economy demands that a slag should be formed by the least possible addition of foreign matter, which makes demands on the heat supplies. In selecting a flux, one object desired is that the slag shall have a purifying influence on the metal. A familiar instance is the basic slags of the converter and open-hearth furnaces, in which phosphorus and sulphur are removed from the liquid metal. The way in which a furnace is working may often be deduced from the appearance of the slag. Its degree of fluidity, and crystalline, or amorphous fracture and colour tell a great deal to a practised furnaceman.

Analyses of slags from blast furnaces show high percentages of silica, lime, and alumina, and of silica and lime from steel-making furnaces. Percentages vary at different stages of the process. A typical analysis of slag from Cleveland pig is as follows:—Silica 27·68, alumina 22·28, lime 40·12, ferrous oxide 0·80, manganous oxide 0·20, calcic sulphide 2·00, magnesia 7·27. The following analysis by Campbell gives the composition of slag from Siemens steel just before tapping, being the average of nineteen heats, using producer gas as a fuel:—Silica 49·40, oxide of manganese (MnO) 16·50, oxide of iron (FeO) 29·79, oxide of iron and manganese 46·29.

The slag from the basic Bessemer process is ground to fine powder and used for manure.

In blast furnaces and cupolas, the silica and alumina in the ore combine with the flux, producing a glassy slag lighter than the molten

and therefore floating on its surface, and drawn off from the furnace at a higher han the metal. Roughly speaking, the al action in the blast furnace is repre- by the equation :—

$$2Fe_2O_3 + SiO_2 + CaO + 3C = 4Fe + CaOSiO_2 + 3CO_2.$$

a matter of fact, the slag produced is a complex silicate.

s play an important part in the economy blast furnace, acting as a filter for ng the globules of molten iron, and also ing the iron from oxidation by the blast. earance they vary, from a whitish almost le mass due to excess of lime, to an opaque ı stone.

is one of those waste commercial products vaiting profitable utilisation in some way. small extent it is used in the form of **Wool.**

g Wool, or **Silicate Cotton**.—A pro- f blast furnace slag, prepared by driving f steam on a stream of molten slag as it rom the furnace. Portions of the slag en blown out in fine shots, which in , draw fine threads of slag after them. reads are sucked through a tube into a er covered with a fine wire sieve, where re deposited. The slag wool is used for g steam boilers and pipes. Being fire- ng it serves as a substitute for asbestos ; it used as a sound-proof packing, and being ted by damp and temperature, is used as conductor in refrigerating chambers. *See* **Conducting Coverings.**

dge Hammer.—*See* **Smith's Tools.**

eker.—*See* **Moulders' Tools.**

epers.—*See* **Permanent Way.**

eve.—A hollow spindle, sometimes also l a quill, or quill shaft. It is a double or spindle, the hole forming the bearing haft which passes through it. A sleeve l for operating two sets of motions in the or in opposite directions.

wing, or **Sluing**.—The turning or re- g motion of a jib crane around its post e purpose of commanding the area of a ete circle, or portion of a circle. It is plished by hand in many small cranes, by pulling at the hook. In all others it is done by power. In a steam crane a set of gears is designed for this purpose, in hydraulic cranes there are turning cylinders lying horizontally, in electric cranes a separate motor is generally employed.

The mechanism of turning includes toothed gears and rollers in steam cranes. Bevel gears from the engine shaft drive to an internal or external ring of teeth on the bed, and rollers on the bed, or round the post, or both, steady the movement. The heavier the crane the larger the slewing ring, which in the largest cranes may be from 30 ft. to 40 ft. diameter. In hydraulic cranes, a chain fitting in a cupped chain pulley usually pulls the crane round. A rack and wheel are sometimes used. In electric cranes, gears are driven directly by a motor through reduction gears, either worm, or spur.

Slide Bars, or **Guide Bars**, or **Motion Bars**.—These are the guides by which the movement of the end of a piston rod farthest from the piston is maintained in a rectilinear course. They are made stouter than mere demands of strength would require, in order to absorb vibration, and their surfaces are of large dimensions to lessen the friction per unit area. All the older bars were plain round rods, or flat faces, but these have been largely succeeded by shapes of cylindrical section with large surfaces, in which the effects of friction are indefinitely delayed.

The maximum load L on a guide bar is $L = \frac{Q}{\sqrt{4r^2 - 1}}$, where Q is the load due to the pressure on the piston, and r the ratio of the length of the connecting rod to the piston stroke. The maximum bending movement on the bar is $\frac{Ld}{4} = \frac{Qd}{4\sqrt{4r^2 - 1}}$, where d is the distance between the supports of the bar. This assumes that the maximum load comes on the centre of the bar, which is not quite correct. The working stress may be taken at about 3,000 for cast iron, and 6,000 to 7,000 for steel.

The old-fashioned style of guide was once very common, in which both top and bottom bars were made separately and fitted. The lower bar rested on bosses cast on the bed.

A distance piece separated this from the top bar, and the lot were bolted down with nuts and lock nuts, each bolt being tapped into the boss beneath. This was a neat way of fitting. Wear was taken up by reducing the faces of the distance pieces, or by inserting thin washers which could be removed. Oil cups were cast on the upper bars, and oil channels cut diagonally in the bar faces. These guides have been made of wrought iron, but they are inferior to cast iron in friction resisting capacity. The grain of a fairly mottled iron is better than the fibrous wrought metal.

Guides which are essentially the same as a single pair of these are embodied in many vertical engine facings, in which two frames bolted to a bed-plate carry the cylinder above them, and have the guides formed on their opposed faces. There is then one slipper block instead of two.

Another form of flat slide bar is constructed more cheaply than that just described. The face of the bed, or of the standard frame, when a single frame is used, forms the face on which the crosshead slides, and strips bolted to the bed face on each side overhang and coerce the crosshead foot. A recess may be planed in the face of the bed or standard. But the edges may be square, or slightly tapered with a view to compensate for wear. For examples, *see* **Slipper Blocks**. Or the facing may stand above the bed, and the strips take a bearing against the edges of the crosshead and have provision, as setting up strips to compensate for wear.

For engines of almost all sizes the practice has become common of casting circular guides in one with the bed and bolting the cylinder against the end of its guides, registered with a turned check. The guides are bored, and the slipper blocks turned. There is no trouble in getting alignment with the cylinder after the work leaves the hands of the machinist. The wearing surfaces are so large that provision for take-up on the crosshead is not always considered essential outside of high-class work, and when given, its amount is but slight. An important feature in these designs, which causes them to compare favourably with the engine beds having guides as first described, is that the metal is massed where the greatest bending stresses occur. The old beds partook much of the base-plate character, which must be bolted to a true and massive foundation to enable it to resist the bending stresses. The massing of metal around the axis of the piston rod and crosshead, and the greater depth given to the beds have conduced to stiffness, without which the present high speed and high pressure engines would soon knock themselves to pieces.

Slide Rest.—The slide rest of a lathe is very properly considered the adjunct which is of the most cardinal importance. It is this which has contributed mainly to render the modern lathe so immensely superior in point of capability, and perfection of results to its predecessors. And many machine tools of other kinds are dependent for their accuracy upon the embodiment of this device in the construction of their sliding parts. The principle is extremely simple, so obvious to us now as to be taken as a mere matter of course. But in its essentials it is little more than a century old. Whether we regard its early history, or its modern development, and the numerous methods of its application, it is of more than mere passing interest. A hundred years ago it was an extremely crude affair; now it exists in so many varieties that every type of lathe has its own special type of slide rest.

Early Rests.—The slide rest was not the invention of any one individual. The idea of the guide principle cannot be credited to any one man. The engineer's slide rest is the last development of many efforts to replace the imperfection of the hands by mechanical guidance. One particular form of the guide principle had been adopted by opticians more than a hundred years before the time of Maudslay. In a work published in Paris in 1671 there are several illustrations of sliding rests. In one the rest or tool post fits by means of vee'd edges over a sliding bar which is moved along the lathe bed or table by means of a screw. It was used for lens grinding, and the bar was also pivoted for grinding to curvatures.

In the tenth volume of plates of the French "Encyclopédie" (1772) there is a slide rest. In this also, as in Maudslay's, the saddle was

clamped upon the lathe bed, but the tool could be operated for sliding within the limit of range of the slide, and operated also to a very limited extent for surfacing. In this, too, there was provision for elevating the tool point. It was done by means of a screw, which on being turned lifted the horizontal slide which carried the tool holder. It was capable of swivelling movement. The construction was much simpler than that of Maudslay's. The bed—it was in no sense a saddle—being flat, was bolted to the lathe. A swivelling plate was pinched to this by means

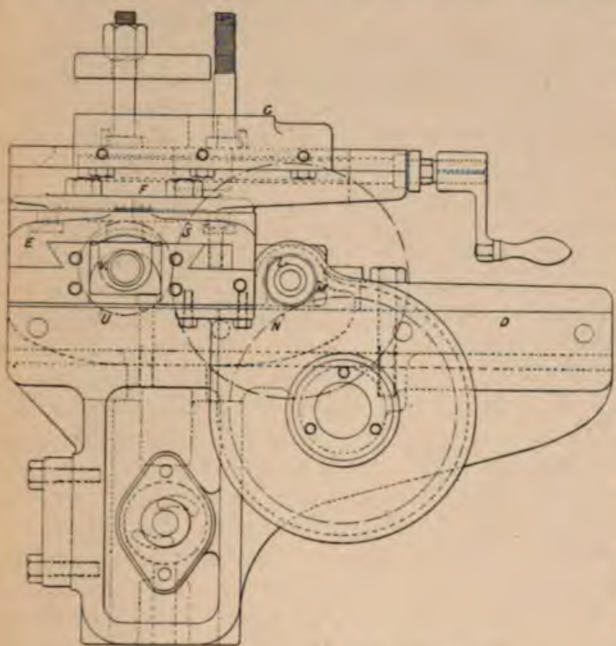


Fig. 189.—Front Elevation of Slide Rest.

of a single screw. The plate carried two uprights or horns recessed to receive legs from the horizontal slide. The slide carried the tool box; the swivelling plate carried the elevating screw; the horizontal slide carried the traversing screw; and the tool holder was moved by the surfacing screw. This must have been an unsteady structure.

Maudslay's slide rest was crude in design by comparison with those with which we are familiar, but it was nevertheless better adapted to the requirements of engineers' lathes than those which had been previously devised. Its essential principles have survived, but in nearly every detail it has been altered. It comprised a saddle, a transverse slide for surfacing, a longitudinal slide for sliding or parallel cutting, which could also be swivelled for taper turning. Both slides were operated by means of screws. It possessed two tool posts. It embodied a provision which is seldom used in modern English rests—that for elevating and depressing the tools. In our rests these are generally packed up if solid, or adjusted as points in their tool holders. But Maudslay's rest contained provision for this by means of pins thrusting longitudinally in diagonal side slots in the transverse slide, the resultant of which two movements was one in the vertical direction. The arrangement must have been a very unsteady one. The sliding was actuated by means of a screw. The saddle also was incapable of automatic sliding, but was of necessity clamped to the bed, which was of triangular section, and shifted as required. Each of the slides also was operated by hand simply.

Joseph Clement had constructed a slide rest, about 1808, without having seen Maudslay's. During the rest of his life he improved it very much. He devised an arrangement by which in turning work on a face plate the speed of the lathe would be self-regulating so that the speed would increase as the cutting tool moved from the circumference towards the centre of the work, and cause equal amounts of metal to be removed at all diameters.

Present Types.—The standard type of slide rest comprises the saddle, which is slid along the faces and edges of the bed. The sliding or longitudinal cutting is effected through this. The saddle carries the transverse slide, moving at exact right angles with the edges of the bed. Surfacing is effected by means of this. Its top terminates in a circular disc provided with a circular concentric groove over which the top slide swivels in a complete circle or any portion of a circle, the edges being graduated into

degrees, and bolts are provided for locking the two at any angle. By means of this, short tapers are turned. Upon the top slide the tool box is carried, and is provided with a traverse movement, effected by hand, for use if required.

Upon this typical and complete model, most slide rests are constructed, some being simpler, others more elaborate in the sense of duplication. Some of the simpler rests have no swivelling movement, others have it to a limited extent only. Some rests have a special function only, that of cutting off work. Others are duplicated, one saddle carrying two and even three rests, capable both of simultaneous and of independent operation. Special rests are constructed for special functions, as curved rests for pulley crowning, capstan rests for carrying four, five, or six tools at one time, front slide rests for convenience of vertical movement, or of being slid clear of the headstock and poppet endwise, hinged or swinging rests, as in the Fox lathes, for convenience of throwing the tool back clear of the work.

The methods of operating rests are numerous, chief among which is that of the leading screw and clasp nut, the back shaft, driving through sliding worm and worm wheel, thence through friction clutches and gear wheels for throwing into and out of operation; ratchet and chain feeds operated from the headstock mandrel or the overhead. Large slide rests for doing heavy work are often made with square edges, as being better able to withstand the stresses of severe cutting than those with vee'd edges. Duplex slide rests are used on large lathes, a cutting tool operating then on each side of the work.

Figs. 189 to 192 illustrate the slide rest for an 8-in. self-acting sliding and screw-cutting lathe, with quick withdrawal. It is one of the standard designs by Messrs Webster & Bennett, Ltd., suitable for lathes fitted with back shafts. A is the clasp nut, opened and closed by the handle B. C is the rack used for sliding and rapid traverse. The main parts of the rest are the carriage or saddle D, the cross slide E, the swivel base F graduated for taper turning, and the tool holder G provided with four clamping bolts.

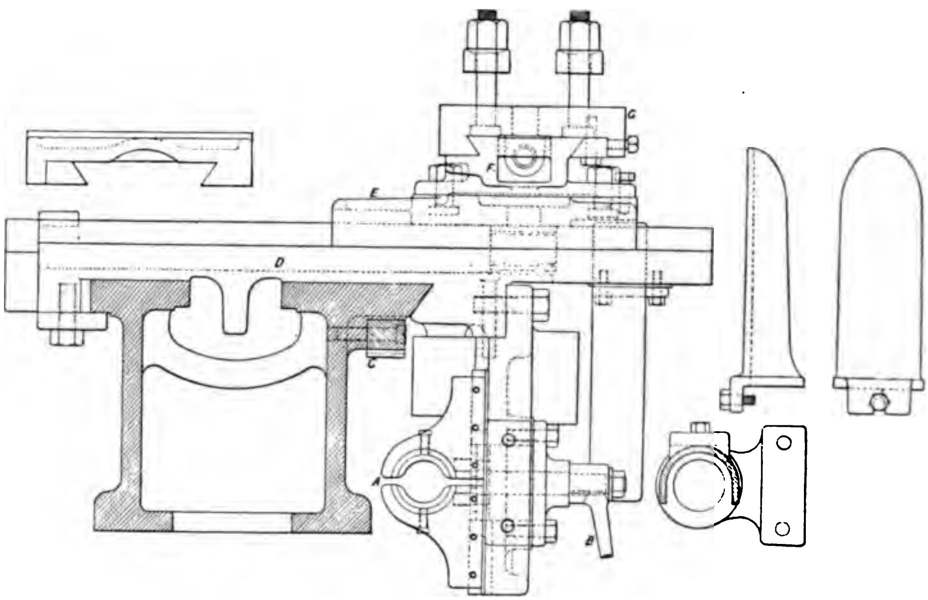


Fig. 190.—Elevation of Slide Rest and Clasp Nut.

The back shaft H, driven by gears from the headstock, is key-grooved to drive the worm J engaging with the worm wheel K, which is keyed on the hollow spindle L. At the opposite end of L is keyed the pinion M. This engages

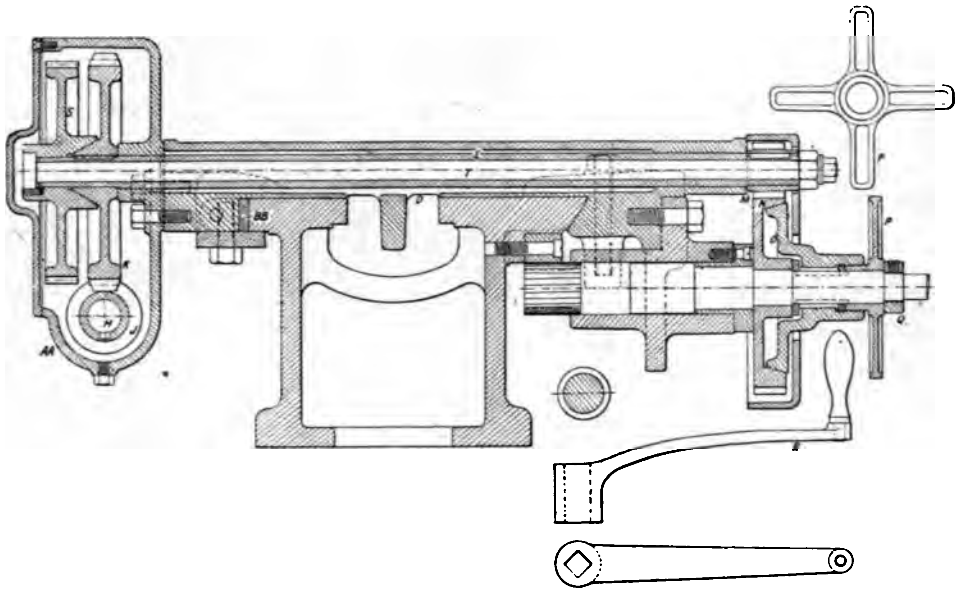


Fig. 191.—Transverse Section through Carriage of Slide Rest.

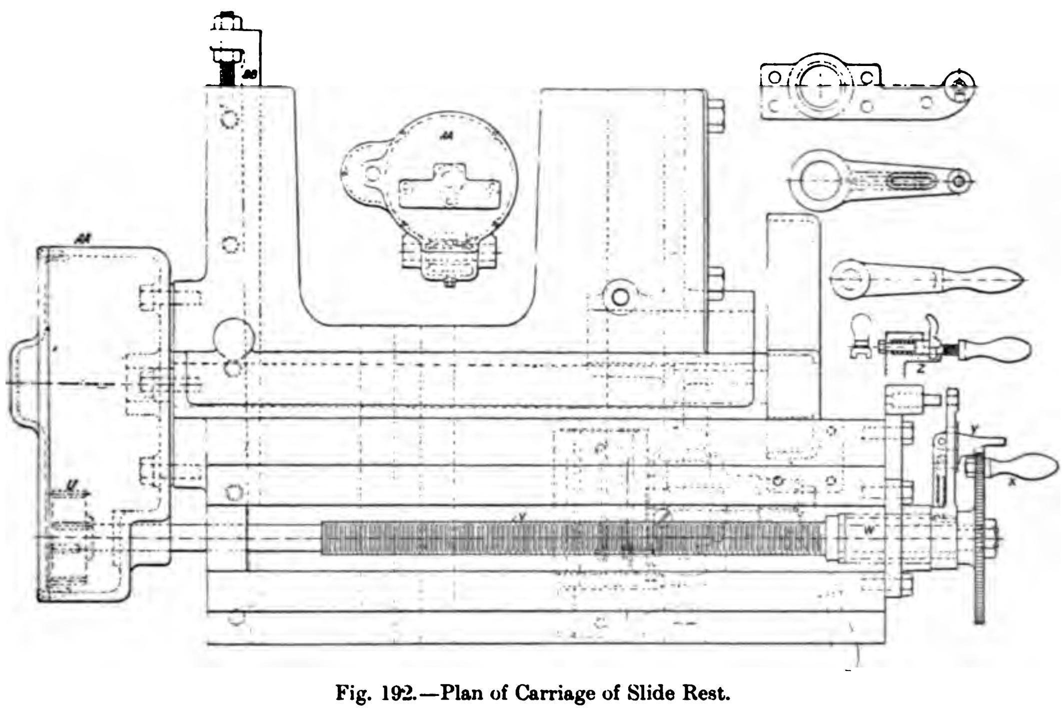
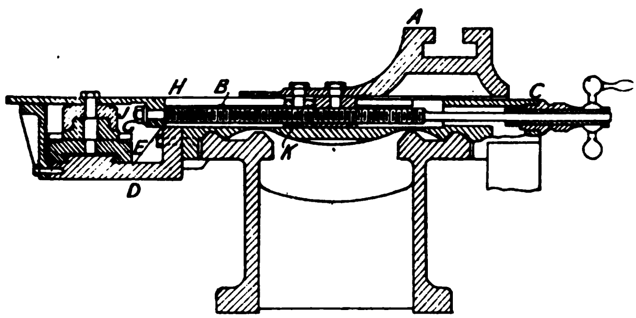


Fig. 192.—Plan of Carriage of Slide Rest.

with the wheel N which runs loosely on the spindle which carries at the other end the pinion that engages with the rack C. This is put into action by the friction clutch O engaging with wheel N. O, keyed on the spindle, is thrown into action by the cross handle P, the



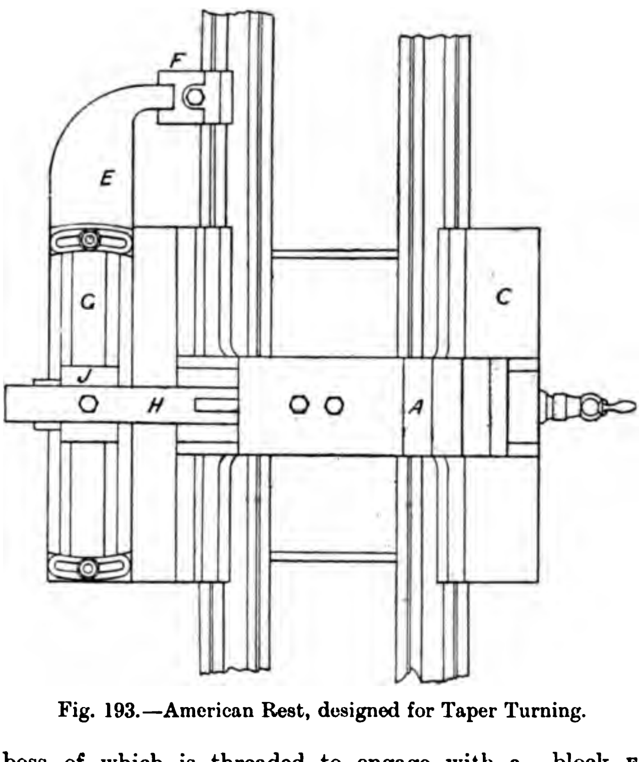


Fig. 193.—American Rest, designed for Taper Turning.

boss of which is threaded to engage with a thread within the extended boss of O. End pressure is thus exerted opposite to the collar Q, so forcing O into frictional engagement with N, and driving the latter, and the rack pinion. The handle R fits over the end of the spindle and is used for racking the carriage rapidly by hand.

Surfacing.—At the back end of the spindle L there is a spur gear S. This is made to partake of the motion of the worm wheel K by being pulled into frictional contact with it, effected by the pull of the rod T on turning the nut at the front end. S then drives a pinion U keyed on one end of the surfacing screw V, so operating the cross-traverse through the nut under the cross slide E.

Quick Withdrawal.—This is effected by a short treble-threaded screw at W, run back by the handle X. The disc to which X is fitted fulfils, with the spring catches Y and Z the function of a division plate for measuring micrometrically the depth of screw threads to be cut. The edge of the plate is cut into a hundred teeth, and the spring catch Y can be dropped into either one of these, starting from a zero division, while the catch Z locks Y to a plate on the front of the carriage.

The casing AA will be noticed which encloses the worm and spur gears at the back shaft. Dirty lubricant can be drained on removing the stud at the bottom. The long wedge take-up strip BB to the carriage may also be observed, as well as several other features to which no special attention is given here.

Fig. 193 illustrates an American slide rest fitted with a taper-turning device. A is the tool-holder, slotted to receive the American type of tool post, B is the cross-feed screw, C the carriage. A bracket D is bolted to the back of the carriage having a long slide with vee'd edges to which a bar E is fitted. This is attached at one end to a sliding block, F, moving on the back vee of the bed, to be clamped to the latter to suit any position of the carriage when taper-turning has to be done. E is always parallel with the bed, but it receives another bar G which has provision for swivel for taper-turning through the curved slots at the

ends, fitted with bolts. A slotted bar, H, makes connection between the block J fitted over D and the cross-feed screw B, on the tightening of the nut K, through which the cross-feed screw passes.

The self-acting feed motion of the slide rests in railway wheel turning lathes is effected primarily in the usual arrangement of a slotted disc at the back of the headstock. But the rod therefrom is carried up and made to operate a shaft overhead, the ratchet and click feed on the slide rest being actuated by means of levers on the overhead shaft.

For firms who want lathes to do heavy but plain turning and boring simply, there are lathes constructed without back shafts or leading screw, the slide rest being operated by hand, or by lever and ratchet feed. Such lathes are made treble geared to take face plates of from 5 ft. to 10 ft. diameter. Some are made also with a movable poppet, and some for face work only. In each type the foundation plate is extended well to the front to carry the pillar rest out far enough to operate on work of the largest diameter within the capacity of the lathe.

An American type of duplex rest is shown in Fig. 194. The two rests are of different heights, the front one being lower to take tools in the ordinary way, while the back one is raised to receive tools placed upside down, to cut on the back of the revolving work. The back rest has also a lateral adjustment, so that the distance between the tools in cutting with roughing and finishing edges can be varied. The front rest has only an independent adjustment by screw and nut C for depth of cut, after setting which, both the rests may be fed in or out simultaneously by turning the main screw below, provided with right and left-hand threads A, and B, as seen.

Mention has been made of the rise-and-fall rests. These are still retained in American practice, though not so much as formerly. The top portion carrying the tool post is hinged on a pin at the front end, and has an elevating screw at the rear, which enables the piece to be raised or lowered, so altering the height of the tool. The objection, of course, is the want of rigidity in the bridge, which is supported at the two ends only, but this is not of much moment in the case of small lathes.

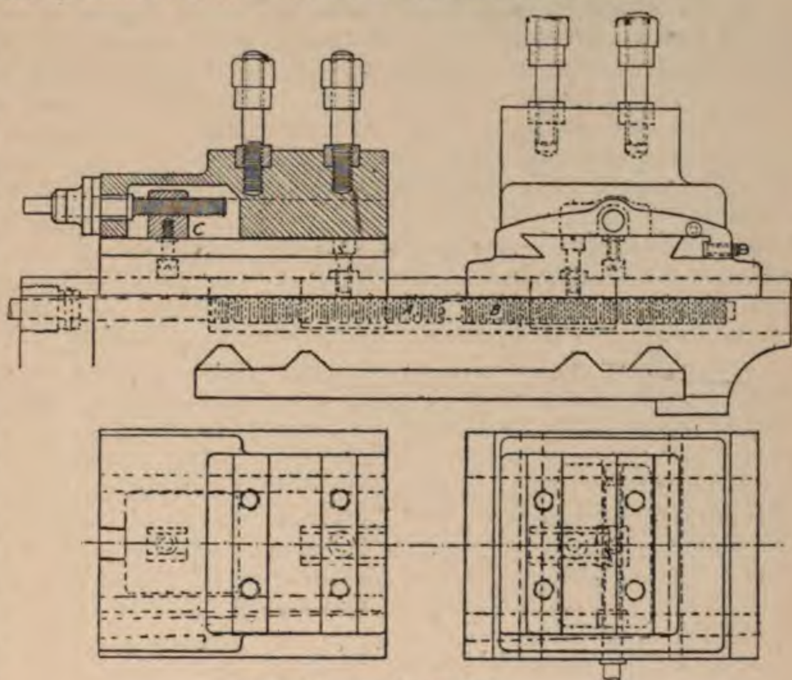


Fig. 194.—Duplex Slide Rest.

Slide Rule.—The first slide rule was made and used by an English mathematician nearly three centuries ago, but as in the case of many modern English inventions, Continental nations have been quicker than ourselves to see the value of, to utilise, and to develop this labour-saving device. The slide rule is used to a much greater extent abroad than in the country of its birth, and the majority of those used here are made by German or French firms.

The slide rule is a great time and brain saver. It performs all manner of operations, and even an illiterate artisan can, with practice, obtain mathematical results which he

would probably be quite incapable of attaining by paper calculation. It solves questions involving multiplication, division, proportion, the squaring and cubing of numbers, the extraction of the square and cube roots, conversion of British weights and measures into those of the Metric system and *vice versa*, vulgar and decimal fractions, all manner of calculations in mensuration, and trigonometry, percentages, strength of beams, belt and pulley problems, gear wheels, strength of shafting, discharge from pumps, application of Ohm's law, horse power of engines, screw cutting, the finding of change wheels, moments of inertia, hydraulic formulæ, &c. &c.

Slide rules are made 5, 10, 15, and 20 inches in length, the longer ones being for office use, and the shorter rules for the pocket. The advantage of a long rule is that, owing to the possibility of finer subdivision of the spaces, greater accuracy is obtainable in reading results, although Messrs B. J. Hall & Co., Ltd., Westminster, have a "Long Scale" slide rule differently graduated from the ordinary rule, for which the advantage is claimed that the precision in reading is, length for length, double that of the lower scale of an ordinary slide rule. A 10-in. rule is sufficiently correct for all practical purposes. They are generally made of boxwood, faced with dull celluloid, on which the figures and divisions show with great clearness. The first impression the slide rule gives one is its total dissimilarity to the foot or any other rule in which the divisions are all uniformly regular. This inequality in the length of the chief divisions, and the irregular number of subdivisions, added to the confusing repetition of the numerals from 1 to 9, has perhaps a repelling effect. The main divisions are unequal, because the spaces represent the logarithms of the numbers on the face of the rule. It is explained under **Logarithm** how multiplication, division, involution, and evolution become respectively addition, subtraction, multiplication, and division by the use of logarithms, and it is because the numbers on the slide rule are spaced according to their logarithms that these operations are possible. No knowledge of logarithms is however needed, all calculations being performed by mechanical methods.

On the face of the rule there are four scales marked on the left-hand side, A, B, C, D, Fig. 200. A and D are on the rule, B and C are on the slide; A and B are exactly similar, and bear the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9; 1, 2, 3, 4, 5, 6, 7, 8, 9, 1. C and D are also similar to each other, but dissimilar from A and B, the series 1, 2, 3, 4, 5, 6, 7, 8, 9, 1 occurring only once, being therefore twice the scale of the upper two. On the sides of the rule millimetres and inches are frequently marked, but these, of course, form no essential part of a slide rule. On the reverse side of the slide are three other scales—one marked "S" giving the logarithms of the sines of angles; a scale of logarithms; and a scale marked "T" giving logarithmic tangents.

The subdivision of the numbered spaces on all four scales needs close inspection, for a complete understanding of these is necessary in order to read results. Every space on the rule from one number to the next is divided into at least ten parts. On A and B the tenths between 1 and 2 are again divided into five parts, so that there are 50 divisions between 1 and 2. Between 2 and 5 each tenth is subdivided into two parts, so that there are 20 divisions between each number from 2 to 5. From 5 to the end of the series there are no smaller divisions than tenths. C and D being twice the scale of A and B, still further subdivision of the primary spaces is possible. Thus there are 100 divisions between 1 and 2, 50 divisions between 2 and 4, and 20 divisions from 4 to the end.

With regard to the value of all these numbers on the slide rule, they have no permanent value except that they are always some multiple or submultiple of 10. Everything depends on the value placed on the figure 1 on the left hand. It may be regarded as 1, 10, 100, ·1, ·01, ·001, &c. But whatever value is given to it, the ratio of value must be borne in mind all along the scale. If on C and D the first 1 represent 100, then the large numbers to the end of the rule will be 200, 300, 400, and so on, the last 1 standing for 1,000; the small numbered divisions from 1 to 2 will be 110, 120, 130, 140, &c., until we reach the large 2 which is 200; the smallest (unnumbered) divisions will be 101, 102, 103,

&c., since there are 100 of these minute divisions between 1 and 2. Again, if the first 1 represent 10, then the main divisions will be 20, 30, 40, 50, 60, 70, 80, 90, 100; the small numbered divisions from 1 to 2 will be 11, 12, 13, 14, &c., up to the large 2, which, as just stated, is 20; the smallest (unnumbered) divisions will be 10·1, 10·2, 10·3, &c., since each subdivision is a tenth (·1) of unity. Ability to thus appraise the value of any subdivision is all-important; it is the main difficulty, yet one that vanishes with a little practice.

The cursor, Fig. 200, is of use in reading off subdivisions as well as in comparing upper and lower scales. It consists of a metal—usually aluminium—frame containing a piece of glass bearing a central hair line, and runs freely in grooves from one end of the rule to the other. Magnifying cursors enable the student to estimate fractional parts of small spaces with greater exactness.

Having closely examined the scales on the slide rule and the manner in which they are subdivided, it now remains to show the method in which it is used, and the beginner is recommended to work out each of the examples given below, and to invent and calculate others of a similar type. Only practice is needed to enable a pupil who "is no good at figures" to make rapid calculations he never aspired to in his wildest dreams.

Multiplication.—Set 1 on the slide to one of the factors on the rule, and against the other factor on the slide read the result on the rule. Owing to the greater subdivision of the C and D scales it is advisable to use them whenever possible. Examples:—

$12 \times 2 = 24$; $12 \times 2{\cdot}5 = 30$; $12 \times 3 = 36$.

Here, Fig. 195, the value of 1 on D is considered to equal 10, and 1 on the slide is placed over 12 according to the rule stated above. Then under 2 on the slide the product 24 is read; under $2\frac{1}{2}$ (2·5) we see the product 30; under 3 the product 36; and so with any intermediate number all along the slide the correct product is found immediately beneath. Again, multiply 85×60. The number 85 being on the extreme right of scale C, the slide must be pushed the reverse way as shown, Fig. 196. Run the eye along the slide to 6 and read the product beneath. We see that it falls on the first of the ten subdivisions between 5 and 6. The 5 is read as 5,000, and a tenth of the distance between 5,000 and 6,000 is clearly 100. Therefore the product is 5,100. But the reader will naturally ask how he is to know that the answer should be read as 5,100, and not 51,000 or 510. The following rule decides the numbers of integers (whole numbers) in any product:—If the slide is pulled out to the left, the number of integers in the product is equal to the sum of the integers in the two factors: if the slide is

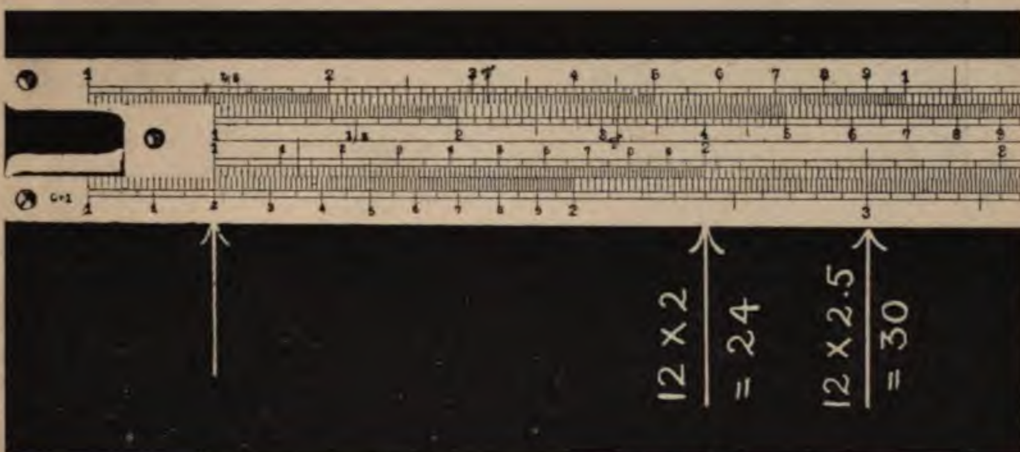


Fig. 195.—Slide Rule. Multiplication.

pulled out to the right the number of integers in the product is one less than the sum of the integers in the two factors. The following examples illustrate the rule:—48 × 50 = 2,400 (left); 32 × 25 = 800 (right); 61 × 40 = 2,440 (left); 29 × 22 = 638 (right). In the last example the product is seen to lie between 635 and 640 on D. The unit figure is, however, exactly determined by noticing that the product of 9 and 2—the unit figures of the factors—must give 8 as the unit figure of the total product. On a 20-in. rule the greater subdivision of the space would indicate 8 exactly, while on a 5-in. rule the difficulty of deciding this figure would be still greater.

When decimals occur in multiplication the position of the point may be decided by the usual rule in decimal multiplication (*see* Vol. IV., page 112). If the last example above were ·29 × 2·2 the two factors would be regarded as whole numbers, and the position of the point, three places to the left, ·638, decided afterwards. The position of the point may also be decided by counting the noughts following the decimal point as negative digits. Thus:—·032 × ·0025: here there are −1 and −2 digits = −3 digits.

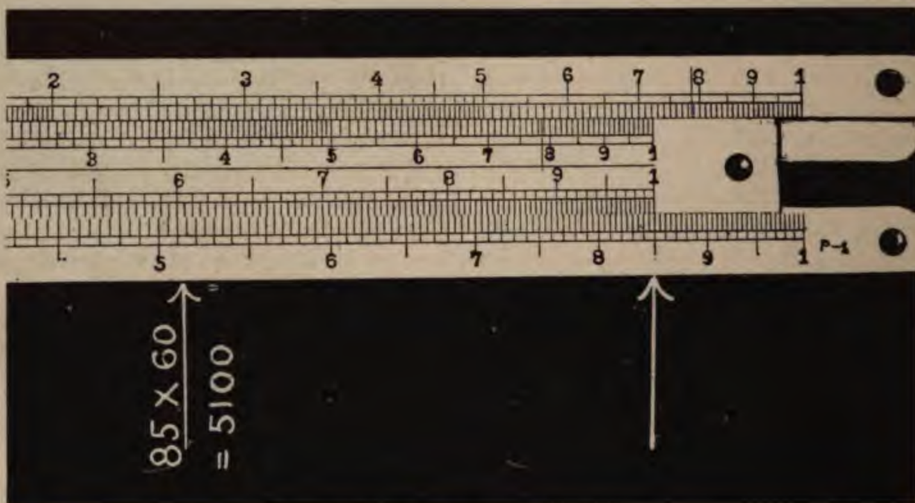


Fig. 196.—Slide Rule. Multiplication.

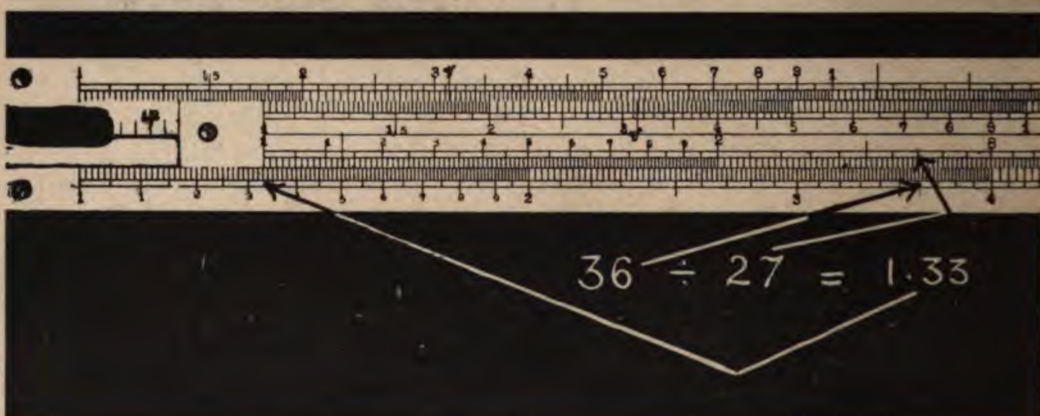


Fig. 197.—Slide Rule. Division.

32×25 on slide rule $= 800$, but as the slide was pulled out to the right the product must be preceded by -3 and -1 digits, or ·00008.

Division. — Set the divisor on the slide against the dividend on the rule and read the quotient on the rule under the mark 1 on the slide. $36 \div 27$. Bring 27, Fig. 197, on the slide over 36 on the rule, and the mark 1 on the left comes over the thirty-third of the smallest subdivisions (hundredths) of the main space, $1-2$. The answer is therefore 1·33. The following rule gives the number of integers in any dividend:—Subtract the number of integers in the divisor from that in the dividend, and the remainder gives the number of integers in the answer if the slide is pulled out to the left; but if the slide is pulled out to the right, add 1 to the answer. In the example above, the slide goes to the right, and the number of integers is therefore $2-2+1=1$. Where decimal quantities are involved, it is best to regard them as whole numbers, and, as in the case of multiplication, locate the point by inspection or by the usual rules. Or the position of the decimal point may be decided by counting the ciphers after the decimal points. $·000029 \div ·025$. Here the digits are -4 and -1, and the difference is -3. To divide 29 by 25 the slide goes to the right, Fig. 198, so that the number of digits following the decimal point in the answer is $-3+1=-2$, and the result is read ·00116. Calculations involving combined multiplication and division of the type $\frac{a \times b \times c \times d}{e \times f \times g \times h} = x$ are also solved. The first divisor e on the slide is set to the dividend a on the rule, and the cursor brought to b on the slide. The next denominator, f, on the slide, is brought to the cursor, and the cursor moved to c on the slide, and so on, the denominators being set to the cursor, and the cursor to the numerators. The sum of the digits in the denominator is subtracted from the sum of the digits in the numerator, and the final answer on the rule under the cursor is modified by the additions or subtractions made when the slide is pulled out to the right.

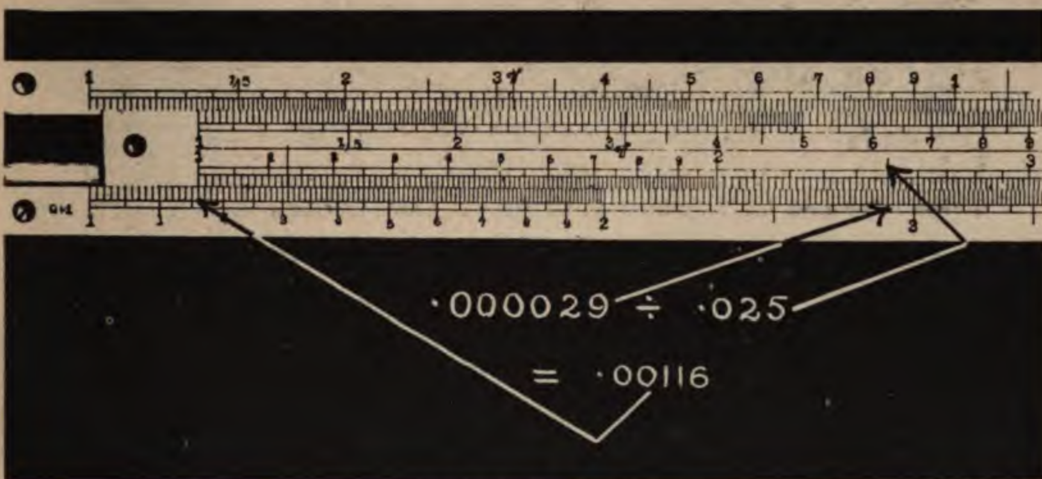


Fig. 198.—Slide Rule. Division (Decimals).

Proportion.—The upper scales, A and B, are more often used for proportion than the lower, although, when the lower scales can be used, the result is read more accurately. It will be observed that when the slide is displaced, as for example in bringing the 3 on A over 2 on B, that the ratio 3 : 2 exists between all the numbers on A and B. Not only does 6 fall over 4, and 9 over 6, but all intermediate numbers as $\frac{7·5}{5}, \frac{63}{42}, \frac{84}{56}, \frac{55}{36·6}$, and the same with the lower scales. The rule for proportion then becomes:—Set the first term of the proportion on the A scale to the second term on the B scale, and opposite the third term on the A scale read

angle the slide is reversed. On the extreme left, minutes are numbered, commencing at 35′. The succeeding numbers indicate degrees only, and these are variously subdivided, the values of the subdivisions being easily estimated when it is remembered that $60' = 1°$. The sine of any angle on the scale S is read immediately above on scale A of the rule, the slide being kept in its normal position, with ends flush. A glance will thus show that sine $25° 12' = \cdot 425$; sine $1° 48' = \cdot 0314$, a cipher succeeding the decimal point when the reading is on the left-hand scale. The operations of division and multiplication of sines do not differ from the methods described for ordinary numbers. The mark 1 on the slide is brought under the

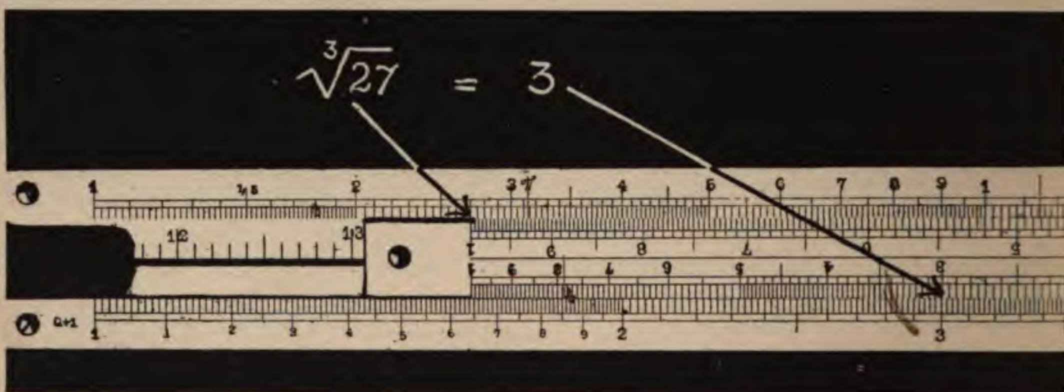


Fig. 202.—Slide Rule. Evolution.

multiplier on scale A, and the result read on scale A opposite the given sine. The tangent scale, marked T, usually commences at 5° 43′ and ends at 45°, and is used in conjunction with the D scale as described above for the sines of angles. The ends of the slide coinciding with the ends of the rule, the value of any tangent along the scale is read on D. If, for example, the cursor be brought over 12° 30′, the value ·221 is read immediately below.

The various calculations described above are far from being exhaustive. As one becomes accustomed to the slide rule it is realised that its operations are as endless in variety as they are inestimable in value. The following examples are virtually but practical applications of the rules given above.

To find the circumference of a circle. This is simply an application of proportion, since the ratio of the diameter to the circumference of a circle is as 7 : 22. If 7 on the slide be set to 22 on the rule, then the circumference of any circle is read on the rule against its corresponding diameter on the slide. The ratio $\frac{22}{7}$ or 3·1416 is marked on most rules by the sign π, and when the mark 1 on the rule or slide is brought against this, the circumference corresponding to any diameter is read. Many everyday applications of this rule occur in engineering. If a wheel is to have ninety teeth and the pitch of tooth is $1\frac{1}{2}$ in., what is the diameter of pitch line? The circumference will be $90 \times 1\frac{1}{2} = 135$, found by setting 1 on C against $1\frac{1}{2}$ on D, and reading the result under 90 on C. Then by bringing 22 on A over 7 on B (or π on A over 1 on B), the diameter of pitch line, 43, is read under 135 on A. If a wheel is 57·5 in. diameter at the pitch line, and is to have 120 teeth, what will be the pitch of tooth? Here it is necessary first to find the circumference and then to divide this by the number of teeth. Bring 1 on B under π on A, and above 57·5 on B read the circumference 180. Then bring 120 on C against 180 on D and read the pitch of tooth, 1·5, on the rule against 1 on the slide. Again, how many teeth will there be in a wheel of which the diameter is 67 in. at the pitch line, and the pitch of tooth 1·75 in.? Here it is necessary to find the circumference and divide it by the pitch of tooth. Set 1 on B to π, and

st diameter 67 on B, read circumference n A. Bring 1·75 on C over 210 on D, and · 1 read 120 teeth.

find the area of any circle, bring the right 1 of A over 7,854 on B—which is marked a special line. Then set the cursor to the eter on the lower scale of the rule, and the will be read under the hair line on the · scale of the slide. What is the total ure on a steam piston, 40 in. in diameter, ı pressure 150 lb. per sq. in.? Worked in tages, the area of the piston is first found this multiplied by 150. Bringing 1 on A the mark ·7854 on B the area 1,250 is l on B over 40 on D. Next bring the left 1 over 150 on D and against 1,250 read 500 on D, the number of digits being esti- d according to the rule for multiplication. n pressure in lb. the load in tons may be ated in one operation. Bring the pressure . per sq. in. on B to 2,852 on A, and the in tons on piston is seen on B against the der diameter in inches on D.

any operations connected with vulgar and nal fractions are rapidly performed, being d, as reflection will show, on the rule for ortion. Reduce $\frac{60}{108}$ to its lowest terms. 50 on A over 108 on B, and under 5 on A 9 on B; $\frac{5}{9}$ is the answer. As this ratio holds good all along the scales, countless tions of equivalent value may be read. To ge any fraction into an equivalent decimal, he numerator on A over denominator on B, over 1 on the slide read the decimal on A. left-hand scale of B should be set under the t-hand scale of A. To change fractions of and yards into inches, bring numerator · denominator as before, and read inches on er 12 (for feet), or 36 (for yards) on B. A e reflection will show that it is thus possible deal similarly with all other weights and sures.

Ietric measures may also be readily con- ed into English measures by the slide rule. inch = 25·4 millimetres, and therefore 5 es = 127 mm. If then 5 on B be set to 127 A, inches on B stand against their equivalent nber of millimetres on A. In a similar way ors may be arranged for the conversion of · quantity into terms of another system. It is merely a question of proportion. A few of the most useful conversion factors are given below:—

B Scale.	A Scale.	B Scale.	A Scale.
Inches - -	Millimetres - -	5	127
Inches - -	Centimetres - -	50	127
Feet - -	Metres - - -	292	89
Yards - -	Metres - - -	35	32
Miles - -	Kilometres - -	87	140
Square inches	Square centimetres	31	200
Square feet -	Square metres -	140	13
Square miles -	Square kilometres -	112	290
Cubic inches -	Cubic centimetres -	36	590
Cubic feet -	Cubic metres - -	106	3
Cubic yards -	Cubic metres - -	51	39
Cubic inches -	Litres - - -	3,600	59
Ounces - -	Kilograms - -	670	19
Pounds - -	Kilograms - -	280	127
Hundredw'hts	Kilograms - -	5	254
Tons - -	Kilograms - -	62	63,000
Tons - -	Metric tons - -	62	63

Problems involving Ohm's Law, $C = \frac{E}{R}$, may also be solved. R, resistance, is set on the slide to E, electromotive force, on the rule, and C, current, is read against 1 on the slide. Example:—If a force of 100 volts be applied to a conductor having 240 ohms resistance, how many ampères will flow through it? Bring 100 on C over 240 on D, and against 1 read ·416 ampère.

To find the velocity of a falling body in feet per second when given the time in seconds:—Set 1 on C to time taken in falling on D, and the velocity is read on D under 32·2 on C.

To find kinetic energy from the formula Kinetic Energy $= \frac{Wv^2}{2g}$, where W = weight in lb., v = velocity in feet per second, and $2g = 64·4$. Example:—A body with mass of 10 lb. is moving with a velocity of 30 feet per second. What is its kinetic energy? Bring the cursor to v (30), on D; set 64·4 on B to the cursor, and the result is seen on A above W (10), on the upper scale of the slide—140 ft. lb.

To find the centrifugal force of a revolving mass. Bring cursor to the number of revolutions per minute on D, and set 2,940 on B to the hair line; set the cursor next to the weight in lb. on B, and bring 1 on B to the cursor; then read the centrifugal force in lb. on A over the

radius in feet on B. In a similar manner the other rules may be applied to practical problems occurring in every branch of engineering practice, but it is unnecessary to give further examples here. Reference may be had to text-books on the subject, while the student himself will realise the more he uses it how infinite are the possibilities of this wonderful invention.

The rules from which these illustrations were prepared have been supplied by Messrs B. J. Hall & Co., Ltd., and John Davis & Son, Ltd.

Slide Valves.—The term is generally restricted to valves with flat faces, as distinguished from piston valves. The slide valve has survived much change, and is still a successful device, notwithstanding the fact that steam pressures are now something like forty times greater than they were when this design was first adopted. But except in general design, there is little real resemblance, since proportions and details of design have been greatly modified.

The earliest design was termed the long **D**. In this the passages and ports were at opposite ends, so that long passages were avoided. But the valves were connected by a bar of **D** section cast with them, so that each moved in unison. Exhaust steam passed away through the body of the **D** section to the condenser.

The slide valve in the original of the form as we now know it was a single valve, situated about the centre of the cylinder, the passages being brought there from the ends. Originally it had neither lap nor lead, for the disadvantages of which *see* **Lap** and **Lead**. Great difficulties arose with increase in steam pressures, partly due to the pressure on the back of the valve, partly to the delays in inlet and exhaustion of the steam through a single port. Out of the first grew the equilibrium, and balanced types of valves; out of the second the double and treble ported designs, and the superposition of a secondary or cut-off valve on the back of the main one.

Action of Valves.—If we look at a common valve we note two or three important features. One is that the arch of the valve is not long enough ever to leave both steam ports open at once to the exhaust port, but that one port must be covered before the other can open to the exhaust. Also that the steam is not admitted to a port until some time after the other one has been closed. The difference measures the expansive action of the steam. Also the width of the exhaust port is wider than that of the inlet ports by from one and a half to twice as much. This gives the freedom to exhaust required. The width of the inlet port, plus the outside lap, equals half the travel of the valve. When the valve is at full stroke with one port fully open, the other port is fully open to exhaust, but the exhaust port is not fully open, being partly covered by the exhaust edge of the arch of the valve. The other exhaust edge has travelled a certain distance beyond the edge of the exhausting port by an amount equal to the outside lap minus that of the inside. And when the valve has closed an inlet port, the width of opening of the exhaust port will be equal to the outside lap minus the inside lap.

This design is suitable for small engines, but with increase of size the reduction in the width of the exhaust port becomes objectionable But by increasing the widths of the ports, and so regulating the stroke that the steam inlet port is only partly uncovered when the valve is at full stroke, the exhaust port can be opened more widely to the escaping steam. This is an exhaust relief valve.

A farther stage in economy is secured by dividing the ports and valve openings, giving the double and treble ported designs, by which the length of stroke for a given opening of the common valve is reduced to one-half, or one-third respectively. An advantage of this design is that the dimensions of the eccentrics are reduced by shortening the stroke of the valve. Further, in this design the friction of the valve is reduced by introducing some counterbalance to the pressure on the back of the valve, by casting openings through the valves, which being filled with live steam maintain the valve more or less in equilibrium, for which reason that term is often applied to them. These designs represent the highest developments of the single slide valve. They give the best inlet to steam, and the best freedom to exhaust with the least movement of the valve, and the steam and exhaust passages are fully opened at full stroke. Usually equilibrium devices are fitted at the backs of these valves in the forms of

springs and rings, so that the steam pressure is taken off the back, until the valve is as near as practicable brought into an average condition of equilibrium.

Fig. 203 shows a very massive slide valve as used for the intermediate-pressure cylinder of a marine engine, built by Messrs Wm. Doxford & Sons, Ltd. The dimensions give an idea of its large proportions, which necessitate a couple of lugs on top for lifting it by. It is of the double-ported type, and the facing of the steam chest is shown in section in relation to the valve ports. It will be noticed that the ports are of different dimensions at top and bottom. The spring shown at A presses the valve against the cylinder face.

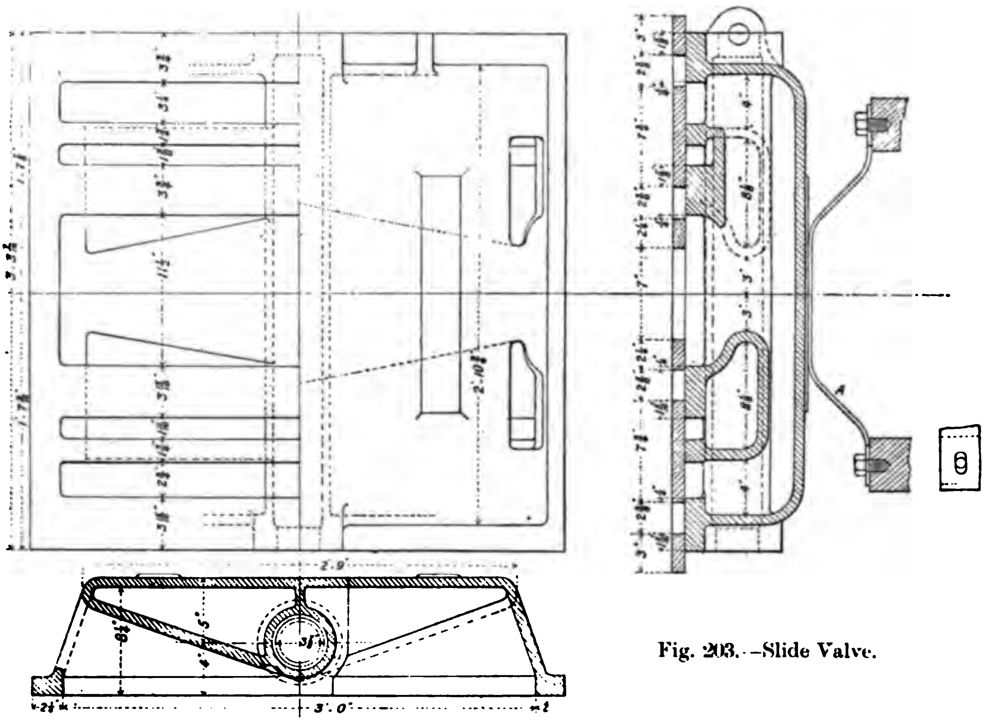


Fig. 203.—Slide Valve.

The term *gridiron* valve has been commonly applied to denote the double and treble ported valves, because of the resemblance of the numerous bars to the gridiron. It is also applied to another form of sliding valve of short stroke, and large collective steam area, used in many large compound tandem engines. An example is seen under **Compound Engine**.

A variation on this design is the Trick valve, which may be considered as one D-valve superimposed on another, giving a steam passage between, in addition to the steam edges at the ends of the valve. The result is, that steam passes through the passage from one end, and enters the same port which is being opened by the edge of the valve to admit steam there. The steam admission takes place twice as quickly as in an ordinary valve, and the opening is of twice the width.

All these are expansion valves in the sense that they cause expansive working of the steam, but they are not what are understood by the term expansion valves, which denotes those in which expansion is produced by a separate cut-off valve working on the back of the main valve, and thus regulating the expansion. In the common valve the amount of lap controls the cut-off and the expansion of the steam. Any quantity of lap can be given to cut-off, say at half stroke, or less. But this is most undesirable, because the travel of the valve is increased thereby, and with increase in travel the exhaust is closed too early, and excessive cushioning results. Hence when cut-off is

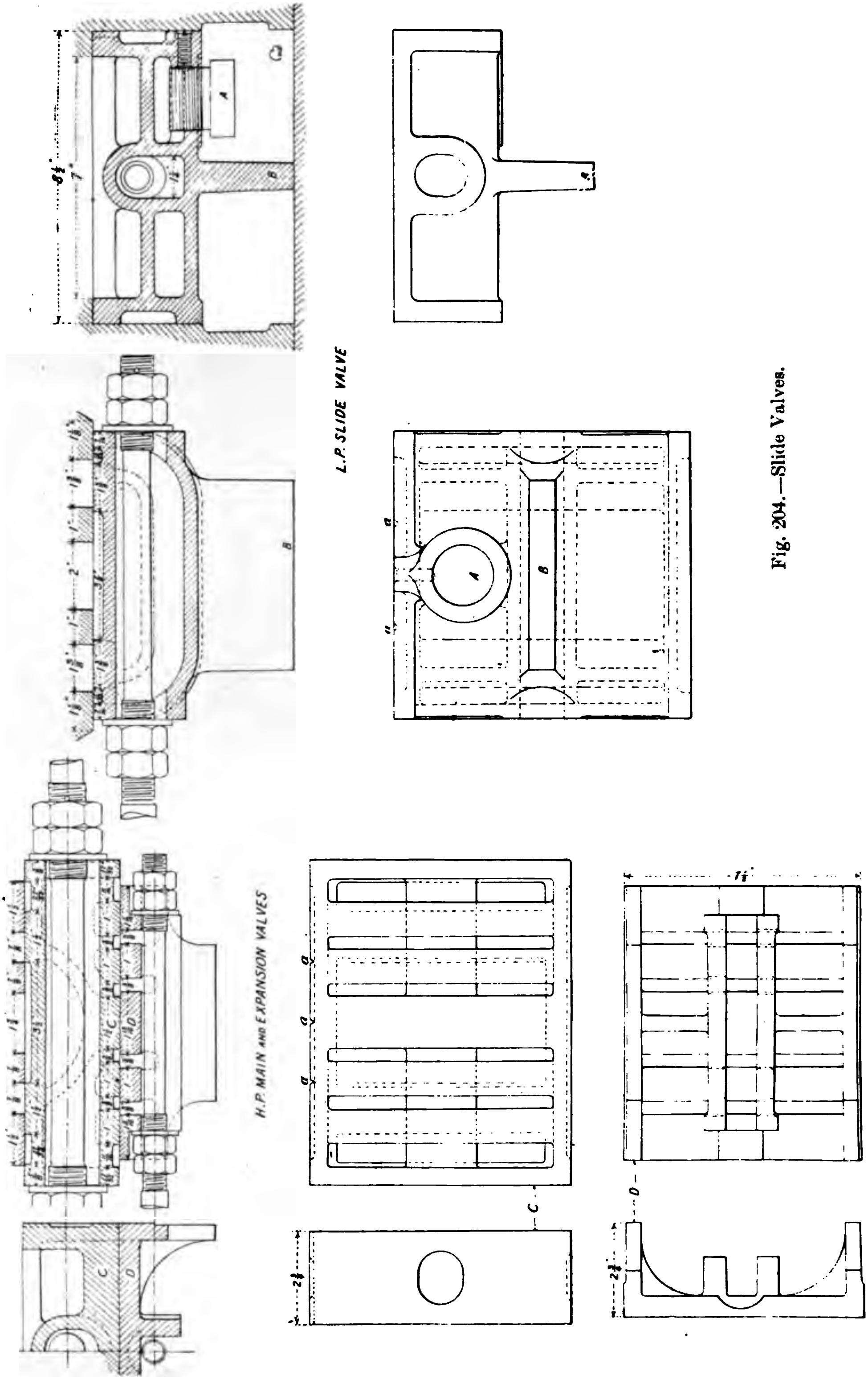


Fig. 204.—Slide Valves.

required earlier than about five-eighths or three-quarters of the stroke an expansion valve is used.

For working these valves two eccentrics are necessary, one for the main, the other for the cut-off valves. Usually the cut-off can be varied by hand gear, or automatically from the governor.

Cut-off Expansion Valves.—The simplest design is that in which the main valve is pierced with two steam ports communicating with the cylinder ports, and the openings of which are controlled by one solid cut-off valve on the back. The main ports may go straight through, or be curved. The central part of the main valve is occupied by the exhaust area and edges.

Fig. 204 shows the valves for a long-stroke tandem compound engine by Messrs Ransomes, Sims, & Jefferies, Ltd. The high-pressure valve is of expansion type, having a cut-off slide on the back. The low-pressure valve is of the Trick type. The faces of these valves lie in a vertical plane, which explains their position in the drawing. A few leading dimensions are given. In the view of the Trick valve shown, A represents a relief valve screwed into the body with a gas thread. B is a rib which bears against the steam chest cover. *a*, *a* are oil-grooves on the top edge of the valve. The valve for the high-pressure cylinder is indicated by C, and the cut-off valve by D. These valves are shown in middle travel. *a*, *a*, *a* are oil-grooves, as in the other valve. In each case there is provision for adjustment by lock nuts, and the rods fit in slots which allow for the wear of the valve faces.

A modification of this is the division of the cut-off valve into two parts, fitted on right and left hand screws, by which the distances between the two parts are capable of alteration for effecting variations in the cut-off. These are well known as Meyer's valves. The regulation is effected by a hand-wheel, or it may be automatic from the governor.

The division of the cut-off valve into two parts is often extended to the main valve also, in the case of long cylinders, with the advantage of shortening the ports. The cut-off slides are adjustable on a rod screwed right and left hand.

Allen's double valve is a special design used for some compound engines having cylinders in tandem. The ports of both cylinders are brought together to be covered by the valve.

Rider's valve is intended to effect the same result as the two cut-off valves with right and left hand threads, but the cut-off valve is in one, and rotates on a concave seating on the back of the main valve, the degree of rotation imparting variations in the degrees of expansion. These valves are either open or closed, according as they work on a semi-circumference, or in a complete cylindrical casing.

Many Rider valves are formed without the concave fitting of the cut-off valve. These are flat, with inclined edges, and are moved transversely over the back of the main valves, the ports in which are made diagonally.

Fastenings.—Slide valves are attached to their spindles in various ways. One of the oldest is to form the end of the rod into a T shape and insert that into a corresponding slot cored in the valve. Many thousands of valves have been secured thus. The objection to them is that they do not permit of exact valve setting, and that they become slack after long service. For small cheap engines they are suitable enough. They bring the rod nearly into line with the valve face, which is its proper position. Their simplicity is a recommendation. There is nothing to become detached, and do injury within the chest.

A device which is more satisfactory, because it can never wear loose, is the valve bridle. This is of circular, or rectangular form, and embraces the entire body of the back of the valve. The valve rod is forged with it, or cottered to it. It has no provision for adjustment.

A screwed rod is more popular, because the screws with a nut and lock nut at each end permit of adjustment when valve setting or re-adjusting. The screwed portion must not make a tight fit in the valve. It fits easily without slop laterally, but clearance must be allowed in the plane perpendicular to the valve face to allow for the wear of the valve and cylinder faces, the clearance being on the side farther from the faces. An open recess only may be made for the rod to drop into, or a slot hole for the rod to pass through, Fig. 204. As the rod has

to be kept as low down as possible, the recess would cut through the arch of the **D** section, and therefore metal has to be carried round the recess or hole within the arch. Cut-off valves frequently have a block dropped into a recess in the back. The block is threaded for the screwed portion of the rod to pass through.

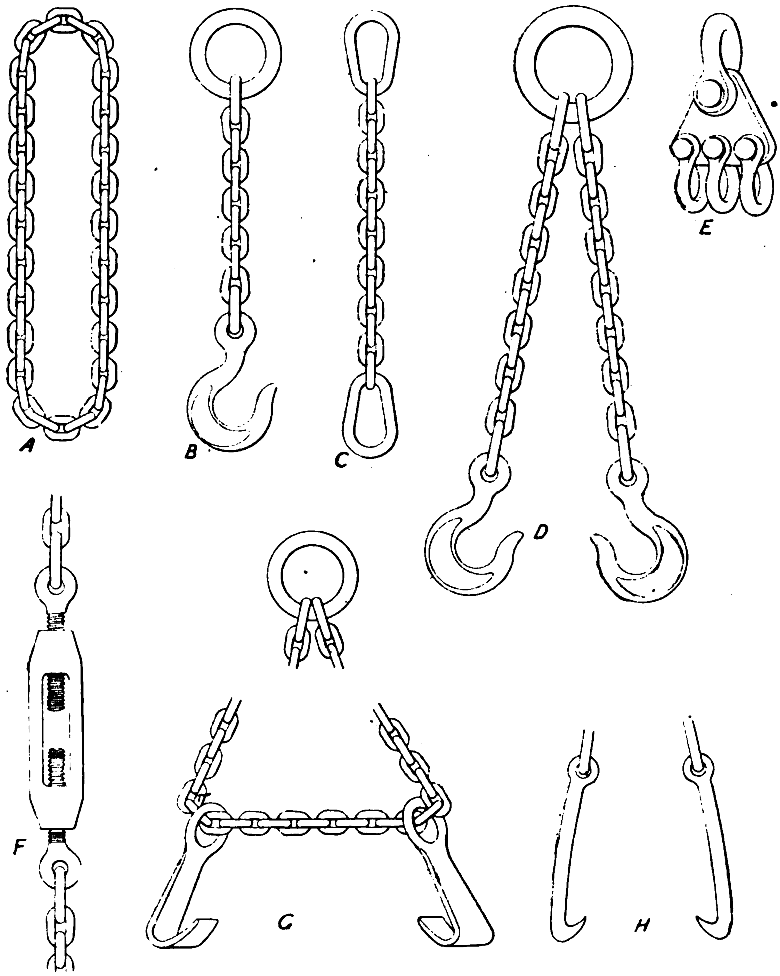


Fig. 205.—Slings.

The lap and lead given to any valve governs the angular advance imparted to the eccentric sheave, or the distance measured in degrees between a vertical line passing through the crankshaft, and a diagonal line connecting the centre of the sheave with the centre of the crankshaft. This angle can be calculated trigonometrically, but it is usual in designing valve gears to lay out everything to actual dimensions. In locomotive shops invariably a full-size model of the valve gears is used in order to prevent errors of any kind. The relations of angular and linear advance to slide valves will be treated under **Valve Gears,** and **Zeuner's Diagram.**

Sliding Friction.—*See* **Friction.**

Slimes.—*See* **Ores, Mechanical Treatment of.**

Sling.—A length of endless rope, or chain, Fig. 205, A, which is coiled round and secured to a piece of work which has to be hoisted by a crane. Or a single length of rope or chain. Rope is used in preference to chain, as being less liable to slip off, and less likely to snap suddenly with overload. An endless sling comprises plain chain, or rope only. A single chain, or *lashing chain*, may be plain, but more often it has an eye at one end to fit over a crane hook, and a hook at the other to be attached to the work, B. Or two collars, C, or circular rings may be attached at the ends, a useful provision for much slinging. Very often one or more elongated back-hooking links are inserted about midway in the chain, for the purpose of inserting the hook after lashing. A double sling, D, is handy for work which requires balancing at two points; or four chains and hooks are often hung from one ring; or a special hanger with three shackles dependent from it is used, as at E. The swivel F is employed for purposes of levelling, to

shorten or lengthen the distance between a crane hook and the work; this is done in foundries to level moulds, and in erecting to set work true. For handling boxes and cases, special slings are required; thus at G the chain has a couple of hooks which engage with the sides of the object, and grip it effectually. The hooks may also be serrated or pointed to afford a better hold, or they may be sharply pointed, like sack hooks. Timber is lifted by dogs or slings, like H, which bite into the log as it is hoisted. The shears of the stonemason are also used for this purpose.

Where lifting is being constantly done, one man, the *slinger*, is allotted the duty of attaching the slings to pieces of work, and signalling instructions to the driver on the crane or overhead traveller.

Slinging. — Securing work in a sling. Common methods of slinging are shown in Fig. 206.

The quickest device is to bend the sling round the work once, and pass the free end through the bight or loop, carry it up and slip it over the hook, as at A. To ensure steadiness and even balance in long pieces the lower parts of the sling may be separated a little. Added security is obtained by passing the free end round once more into a second bight, B.

Such devices are suitable for pieces of work which are not of large dimensions across. Length is immaterial, because a long piece can be steadied by a man at one end. But a broad article cannot be embraced by an ordinary sling. Two ropes are then used, one to embrace the work, the other to be passed through the ends and hitched on the crane hook, as at C.

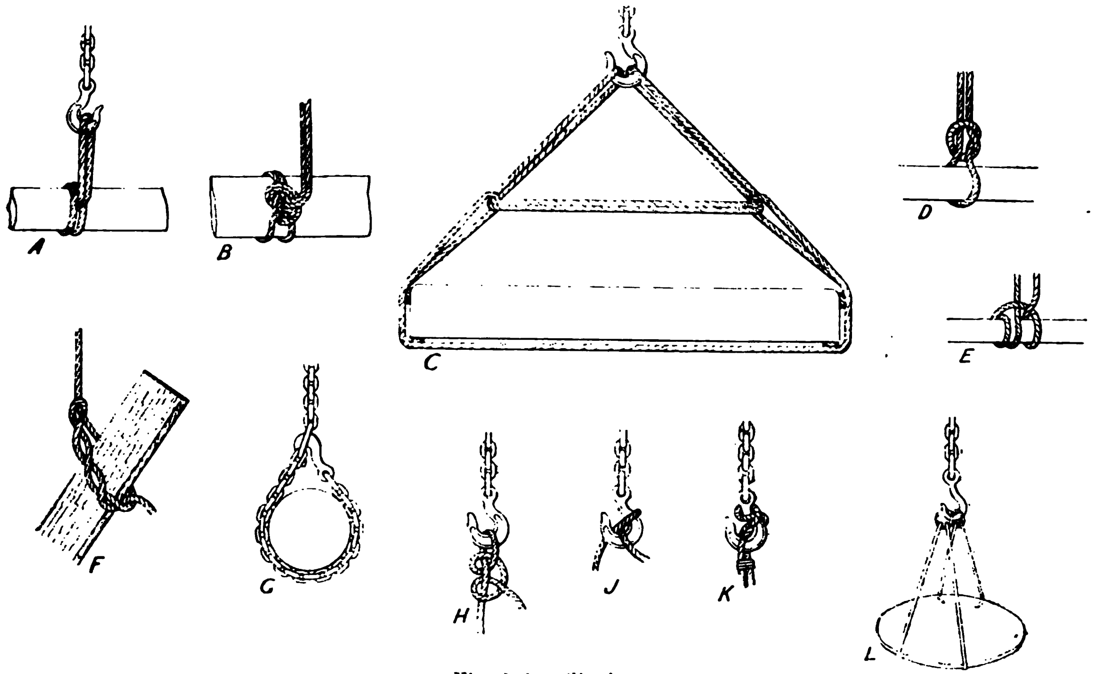


Fig. 206.—Slinging.

A slip knot is used for slinging. An overhand knot is first formed, and the standing part of the rope is passed through the knot and pulled taut, D. This knot is frequently duplicated on a long piece of work, so maintaining the latter horizontally.

A magnus hitch is used for slinging planks and poles on outdoor work. The rope is taken round the plank three times, and passed up through the last bight, E.

A timber hitch is made by passing the bight of the rope round the timber and round the

standing part, and back round itself a number of times, F. It cannot slip.

Many a lift is made with a single sling chain hung by its eye from a crane hook by simply bending it round the object, and inserting the hook of the sling in one of the links, G.

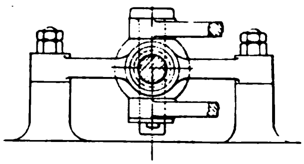
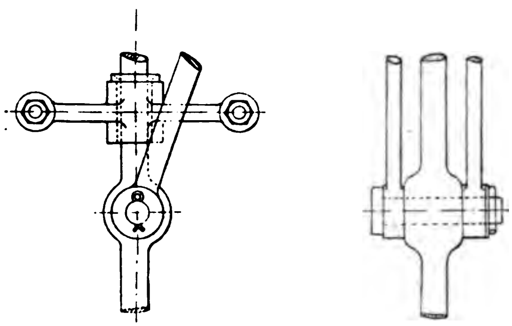


Fig. 207.—An Early Slide Bar.



When a timber hitch, or a magnus hitch is made at one end of a single rope, the other end can be attached to the crane hook by a single or double Blackwall hitch, J or K, or by a sailor's knot, H. The last is the most readily made, and cannot slip.

There is much work which cannot be safely slung in this way, either because it is too large, or because the sling would slip, or because a truly level lift is requisite. This is the case more especially in foundry, boiler shop, and erecting shops. Large plates and rings are examples.

A plate may be lifted edgewise by a common sling chain or rope without much risk of slipping, provided the lower bends of the chain are spread well out. But plates may slip out of the slings. Neither can a plate be lowered flatwise in this way. Hooks, L, and chains with or without swivels are frequently used in such cases. When, as often happens, plates have rivet or bolt holes around their edges, the safest way is to use eye bolts, or even common bolts. Hooks at the end of sling chains may be passed through the eyes of eye bolts, or the shutting link of the sling chain may be made to encircle the body of the bolt, passed through it before the nut is put on. Or a bar may be passed through a hole, and the bar slung to the crane hook.

Slip.—*See* **Screw Propeller**.

Slip, Slipping.—Relates specifically to the slip of riveted plates. *See* **Riveting**.

The slipping of parts of mechanisms under overloads is often provided for in order to avoid risk of fracture. A point often urged in favour of belt drives and feeds over that of gears is that the first will slip, while the second will fracture with overload.

Slipper Blocks, or Crossheads.—These are coupled because they are frequently united in one and the same piece. In the old style of slide-bar the crosshead was entirely distinct from the slippers, but that practice is generally abandoned now. The crosshead, when a separate piece, may be defined as the element to which the piston and connecting rod of an engine or pump are both united. The slide or slipper blocks are those elements which are coerced by the slide-bars or motion-bars. Such an arrangement adds largely to the work of fitting, and is unnecessary. In nearly all the examples shown here, the crosshead and slipper block are combined in one.

The slipper blocks which are used with flat guide bars of the older design, are castings usually, and if large they are lightened by coring out.

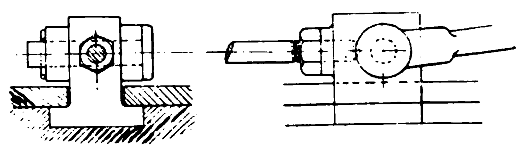
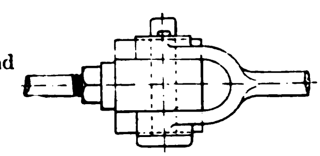


Fig. 208.—Crosshead and Slipper Block.



They have inner flanges moving against the edges of the bars, and are bored to receive the pin, the central part of which is embraced by the ends of the piston and connecting rods.

There is an old design, Fig. 207, which is

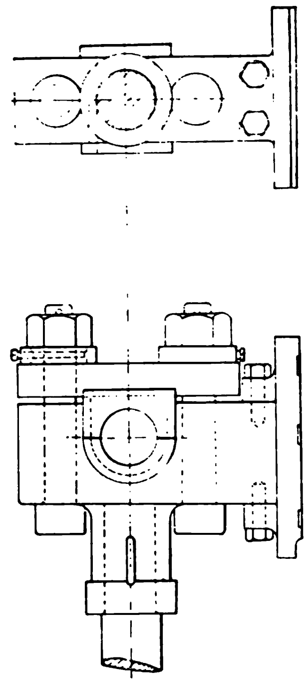


Fig. 210.—Crosshead and Slipper Block.

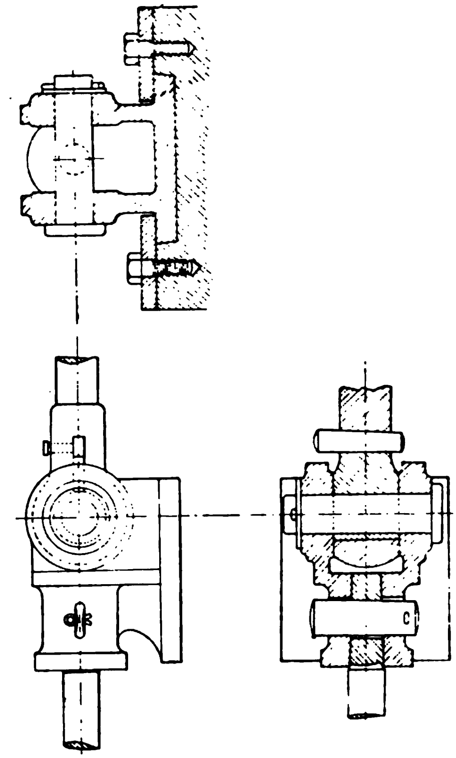


Fig. 211.—Crosshead and Slipper Block.

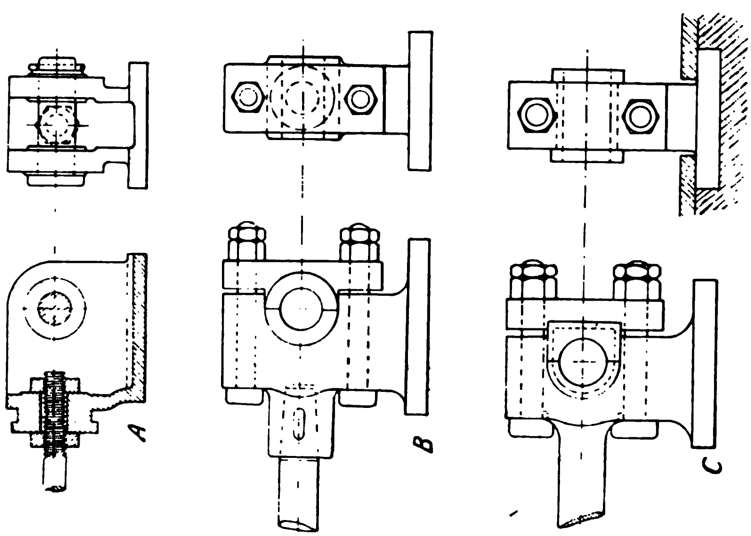


Fig. 209.—Crossheads and Slipper Blocks.

seldom made now, because the wearing surfaces are too small, in which a boss formed the guide to an extension of the piston rod. The boss was in the centre of a bridge piece, and the connecting rod was pivoted to a boss on the piston rod behind the bridge.

A single crosshead, that is one which fits between one pair of flat guides only, is shown in Figs. 208 to 211. These designs and others in subsequent figures may or may not contain provision for taking up wear. The latter may be done in several ways, as seen in the various illustrations.

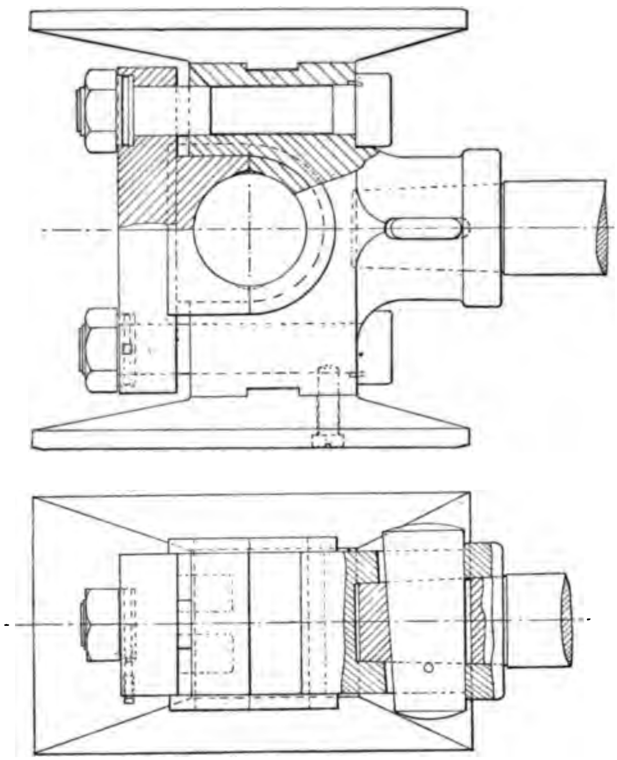


Fig. 212.—Crosshead and Slipper Blocks.

Crossheads for flat guides made on one surface only of bed or upright frame are of the forms shown in these Figs. Either solid bosses, or caps may be used to receive the crosshead pin.

Fig. 208 is a crude form, in which the piston rod is screwed into the crosshead and secured with a lock nut. The connecting rod is forked, and pivots on the pin. Three types are illustrated in Fig. 209. A has the piston rod passing through a hole and locked with a couple of nuts, while the connecting rod lies between the cheeks. B has the piston rod fitted with a taper and cotter, and a cap holds the pin, with adjustment for wear. Both in this and in C the connecting rod embraces the outside of the crosshead, but in C brasses are provided, and the piston rod is solid with the crosshead. Fig. 210 is very similar in design, but the bottom portion is fitted separately, and has three white metal strips inserted to form a good wearing face. In Fig. 211 the connecting rod fits between the crosshead cheeks, and has a divided brass which is closed in from time to time by filing on the joint face and driving the take-up cotter further in; a set-screw locks the cotter.

Fig. 212 is a larger class of crosshead by Messrs D. Stewart & Co., Ltd., with the slippers tongued on, and secured with countersunk screws. This is for a mill engine, and the breadth over the slippers is 34 inches. Fig. 213 is another, with slippers secured by hexagon set-screws, and having white metal strips *a* cast in the faces. This is for a marine engine, made by Messrs Wm. Doxford & Sons, Ltd. Fig. 214 is a simple type of crosshead for cylindrical guides, such as are used on many of the smaller engines, including those for winch and crane driving. A cylindrical type with arrangement for taking up wear is illustrated in Fig. 215; the slippers fit in vee grooves and are drawn up the sloping faces by means of tee-headed bolts *a*, *a*, removing thin washers between the crosshead and the slippers as required to allow of this movement.

A large crosshead of the circular type, for a vertical engine with guides bored to 29 in. diameter, also by Messrs D. Stewart & Co., Ltd., is shown in Fig. 216. The principal feature of interest is the method of fitting the slippers, which are adjusted outwards by forcing in a couple of steel wedges, thrust down by nuts on two studs, a thickness piece under the head of each wedge being thinned to allow of the

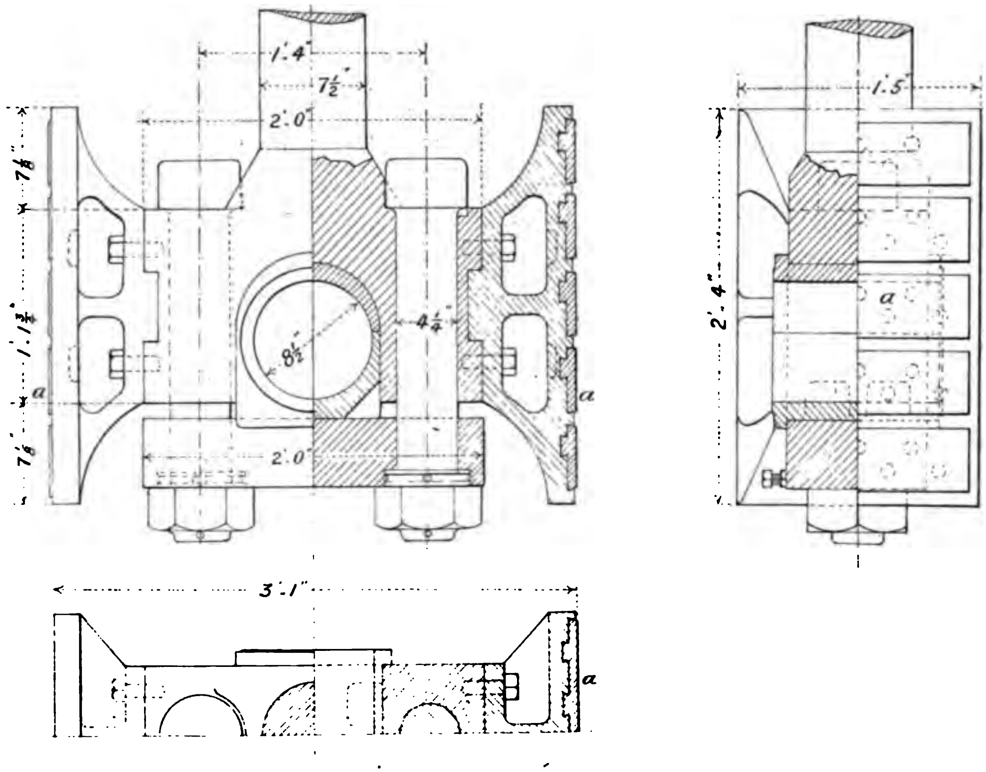


Fig. 213.—Crosshead and Slipper Blocks.

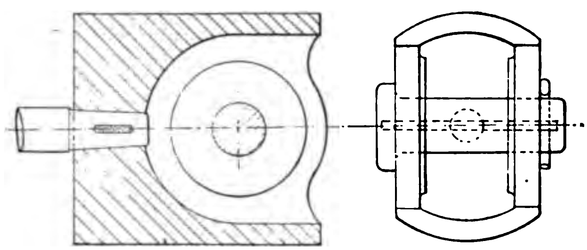


Fig. 214.—Cylindrical Crosshead.

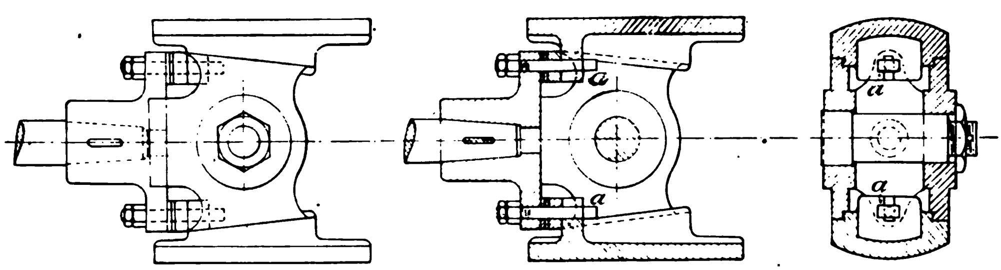


Fig. 215.—Cylindrical Crosshead.

adjustment being effected. A row of set-screws on each slipper serves for locking purposes; Babbitt metal strips on the convex surfaces of

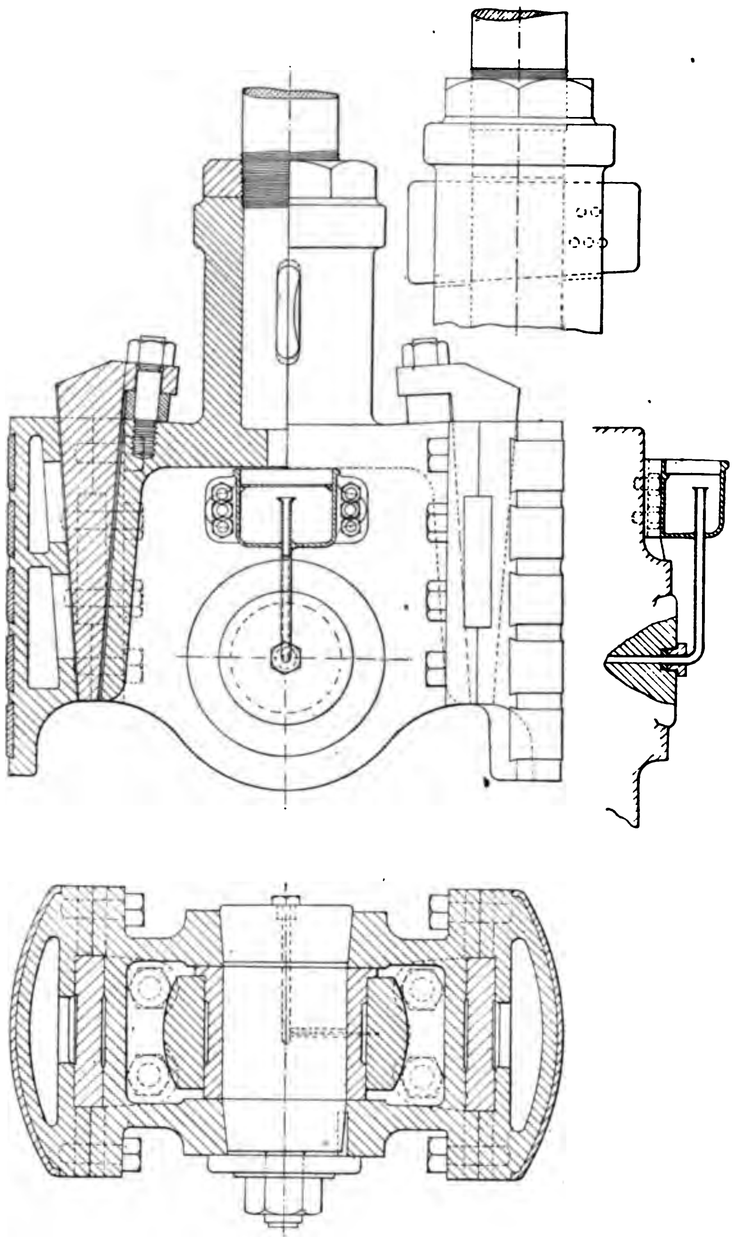


Fig. 216.—Cylindrical Crosshead.

the slippers form good wearing faces. The Babbitt is $\frac{5}{16}$ in. thick. The lubricating device for the exterior of the pin will be noted; it includes a syphon tank, and a pipe communicating with a hole passing through the pin. The latter, as will be seen, is fitted with two taper portions into the crosshead and secured with a short key, and a nut and washer. A different class of crosshead, also by Messrs Stewart, is

shown in Fig. 217; it is for a horizontal pumping engine. The slide ways are situated 35 in. apart, centre to centre, and the forged crosshead, having four turned places for rods, and a centre hole for cottering the main rod to, is fitted with separate slippers, bolted on. Their upper faces slope, to match the under faces of the take-up strips on the guides.

Slippery Iron.—A rather tough mottled grade of iron which is harder than grey, but not so close grained as white. It is capable of taking a very smooth polished surface suitable for sliding faces, as those of crossheads and slide bars, hence the term.

Slipping Clutch.—A clutch which is set or adjusted to slip at an overload. The **Weston Clutch** is of this type. *See also* **Shaft Couplings.**

Slit Bar.—A lever bar which has a slit down the centre, along which a pin can be adjusted. The device is used in numerous mechanisms for altering length of stroke. Examples are seen in many feed gears, and in rams of shapers.

Slitting Mill.—A mill in which flat bars are slit or divided into strips which are supplied as nail bars to the nail makers. The rolls used are provided with circular collars or discs, and those on upper and lower rolls act as circular shears, severing the bars which are passed between them.

Slot Drilling Machines.—These are used for cutting slots, cotter ways, or keyways by means of revolving cutters, which operate with their ends. A traversing movement is imparted to either the work or the drill, equal to the required length of slot, and several to-and-fro motions are given, the drill being set a little deeper each time until the proper depth is reached. The design of a machine depends partly upon its size, the smaller ones usually having a travelling head which carries the cutter spindle, while in larger ones it is often the table that is moved. An automatic trip mechanism is necessary, to effect the reversals, and this must be capable of adjustment to accommodate varying lengths of slots. The accompanying illustrations, Fig 218, show a type of slot drill made by Messrs George Richards & Co., Ltd., capable of producing slots up to 20 in.

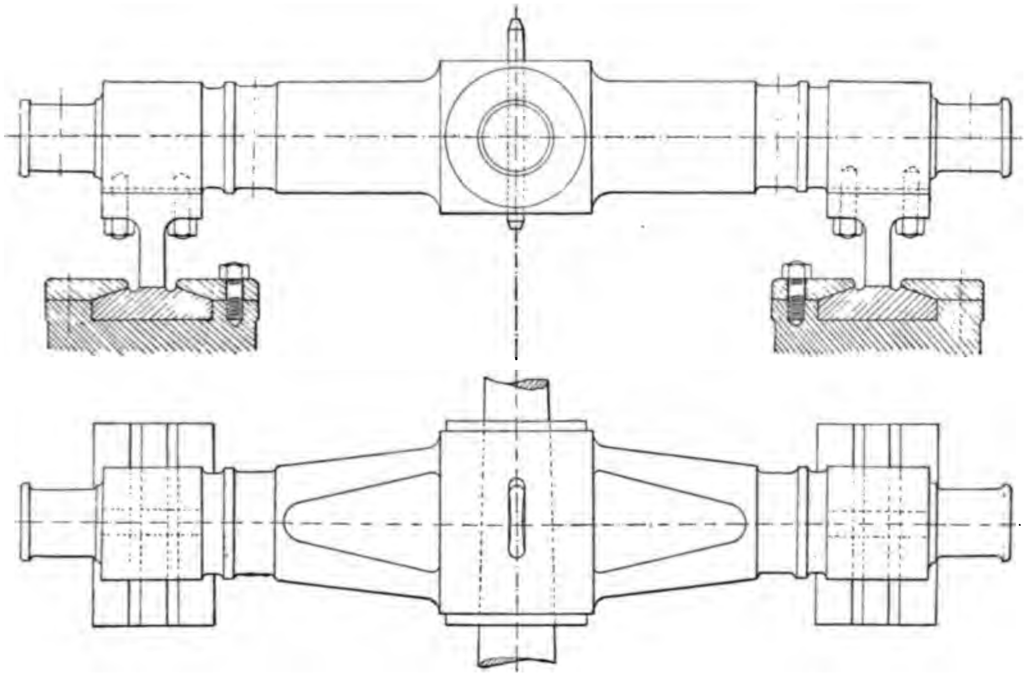


Fig. 217.—Forged Crosshead.

long and 1 in. wide. The pillar has a slide face upon the front, on which fits the spindle head A carrying the spindle B in conical bearings at top and bottom. The shanks of the cutters are held in conical grips. The spindle pulley C is driven by an endless belt running over the pulleys D D and two vertical idlers E E; the position of the slide does not affect the driving. The three-stepped cone F is belted from the countershaft, so driving its companion pulley D at either of three different rates, the other pulley D being only an idler. The longitudinal self-acting movement of A is effected through the screw G, turned alternately to right and left by worm gear at H, actuated by the pulley J, driven from K. J turns the shaft of the

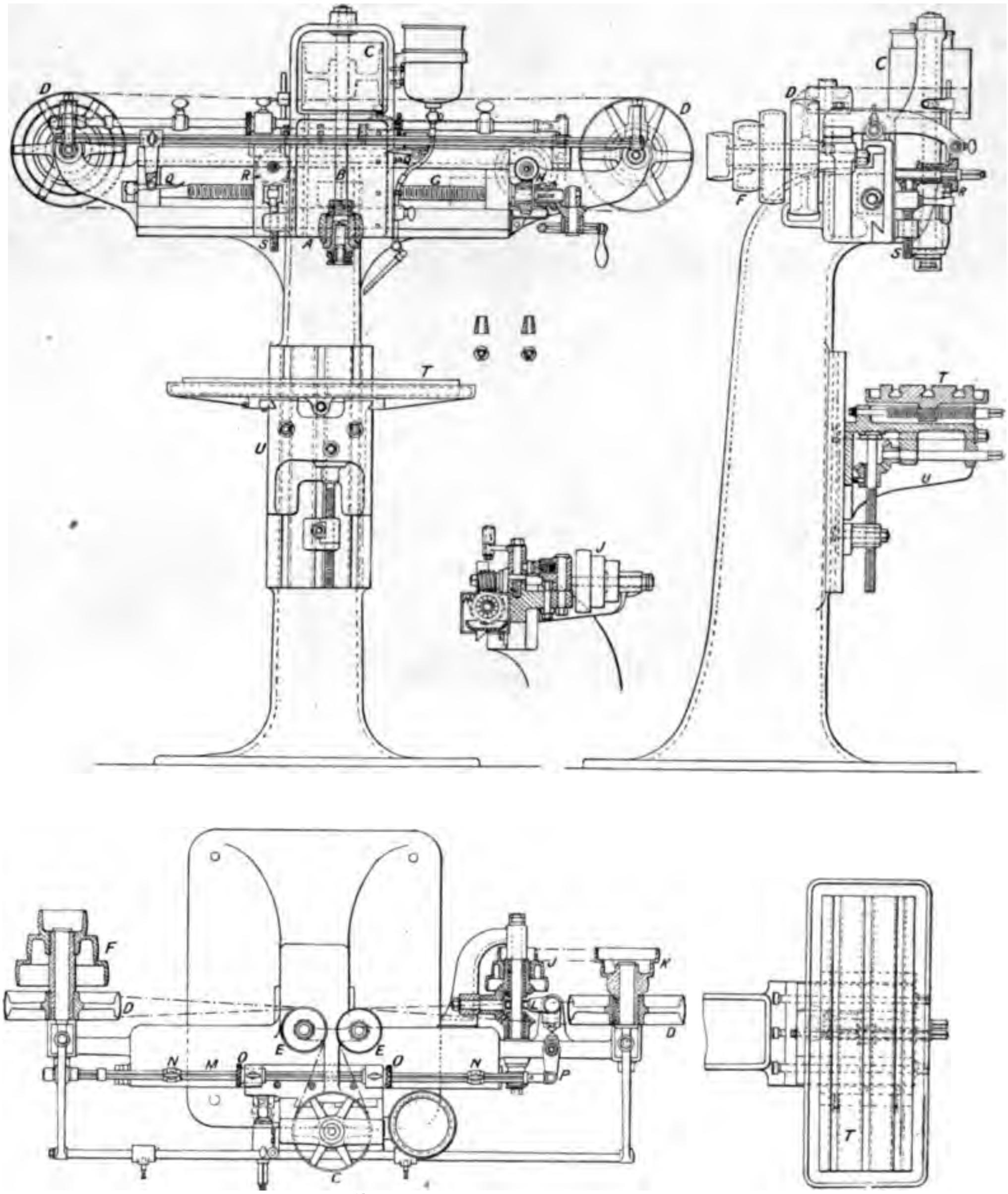


Fig. 218.—Slot Drilling Machine.

worm through intermediate mitre gears at L, a claw clutch being interposed, so that when it is thrown to the one or other side the motion of the shaft is reversed. This reversal is automatically effected by the trip rod M, provided with adjustable dogs N, N, struck by collars O, O, fitted to lugs in the saddle; the collars are threaded, so that they can be finely adjusted, and they are secured with small thumbscrews. As the rod M is moved endwise it pushes the lever P, which has a pointed end to operate a lever that moves the clutch L. A spring locks the latter in either of its two positions until the trip mechanism works again.

The automatic down feed is derived from a screw and ratchet arrangement, comprising two pivoted fingers Q, Q hung in bearings adjustable along a rod at the front. As the saddle reaches the end of its travel in each direction, one of the fingers engages in a tooth in a ratchet wheel R, turning the latter a little, and thence through mitre gears, a vertical screw, S, passing through a lug at the side of A. The work is fastened to the table T, adjustable by screw across the face of a knee, U, which itself can be elevated or lowered upon the planed face of the column by means of a screw and handle, and secured with bolts. A drip can is provided for supplying lubricant to the drills.

A favourite method of operating a table, when it is slid for feeding, is by means of a crank disc and connecting rod. Machines resembling slotters in outline are constructed with a fixed spindle, and a table beneath, slid to and fro by this crank device, the distance being varied by sliding the crankpin in a slot across the disc. In such cases a ratchet and pawl is fitted to feed the spindle down after each stroke.

For cutting cotter ways which have to pass right through the work, such as in piston rods, drill sockets, &c., it is more economical to work from both sides of the shaft at once, the machines for this class of work being constructed with a double spindle saddle, sliding along a bed, over which the shaft is held in supports. The saddle is moved to and fro by a crank disc, and each drill spindle is fed in to a small amount at each traverse. When the slot is nearly through, one drill is withdrawn, and the other completes the removal of the metal.

The drills used are generally of the form shown in Fig. 219, A having a flattened end formed into two lips, with a concavity at the centre, which allows the metal to clear. Some-

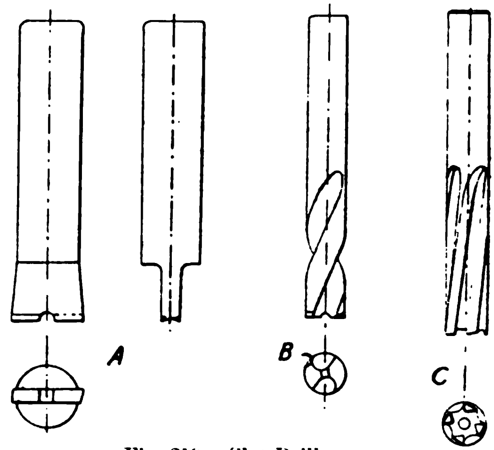


Fig. 219.—Slot Drills.

times old twist drills are utilised, by grinding them as shown at B; they cut freely. C shows the type of drill used on Messrs Richards' machine; it has four cutting edges, standing out at the bottom to afford good clearance, and they slope with a spiral form upwards.

Slotting Machines.—These differ from planing and shaping machines in possessing a vertical movement of the tool, which travels downwards to the work, bolted to a horizontal table. As the pressure of the cut is nearly in a direct line with the body of the ram, and as the pressure on the tables tends to press them more closely together, it follows that heavy cuts can be taken, with a minimum of springing. The slotter is, therefore, well adapted for slogging work on heavy castings, and especially forgings which have to be reduced to a considerable amount. The machine is also handy for certain classes of work which are better laid horizontally, so that the attendant has a full view of the surface, and is able to work the tool around to lines which would be difficult to see on a planer or shaper. As the name implies, the slotter is very suitable for cutting out slots and keyways; to enable such internal work to be handled easily, there are longitudinal and transverse

motions of the slides, and a circular table on top provides for working around curves.

The chief points of difference in slotters are concerned with the arrangements for reciprocating the ram. Some form of quick return is essential in all but the very smallest machines, say of 6-inch stroke, so that the ram shall rise rapidly to avoid waste of time. A very common method is that of a slotted link pivoted at one end, and rocked up and down by a crank-disc, the pin of which engages in the slot, and moves the link at a quicker rate when it is near the pivotal point than when at the other extremity. A connecting rod pivoted to this end of the link transmits the movement to the ram; this being the Whitworth motion. Fig. 220 shows a machine having this arrangement; here the cone pulley A, on the shaft of which is a fly-wheel, drives a pinion geared up to the spur wheel B on the shaft C, on which is the disc D actuating the link E. The latter is pivoted at F, and rocks the rod G, coupled to the ram H. A counterbalance weight, J, prevents the weight of the ram from causing uneven movements. The pin of the rod G is attached to the ram through the medium of a sliding block, K, which can be slid up or down in a slot in the ram and secured by a nut; the object of this is to enable the ram to be adjusted up or down within a certain range, to suit the depth of the work, and the place where slotting has to be done. The ram has two tool straps, and there is a block secured on the front face to take the endlong thrust of the tool. The feeds are derived from the disc L, having a cam groove on its face which operates a rocking lever, M, and thence a ratchet mechanism at N which connects to the feed screws for the tables, put into operation by sliding gears. The disc L is so set that the feed is put on just before the tool commences to cut. The amount of feed is varied by sliding the pin of the rod attached to M in or out in the slot in M. When a self-acting circular motion is provided for the table, a train of gears connects up from the ratchet wheel shaft to a shaft on which is a worm engaging with the wheel around the table. When tapered slotting has to be done, the upper table is hinged, and a screw enables the operator to tilt it to suit the required degree of taper; the circular table, of course, partakes of the same slope.

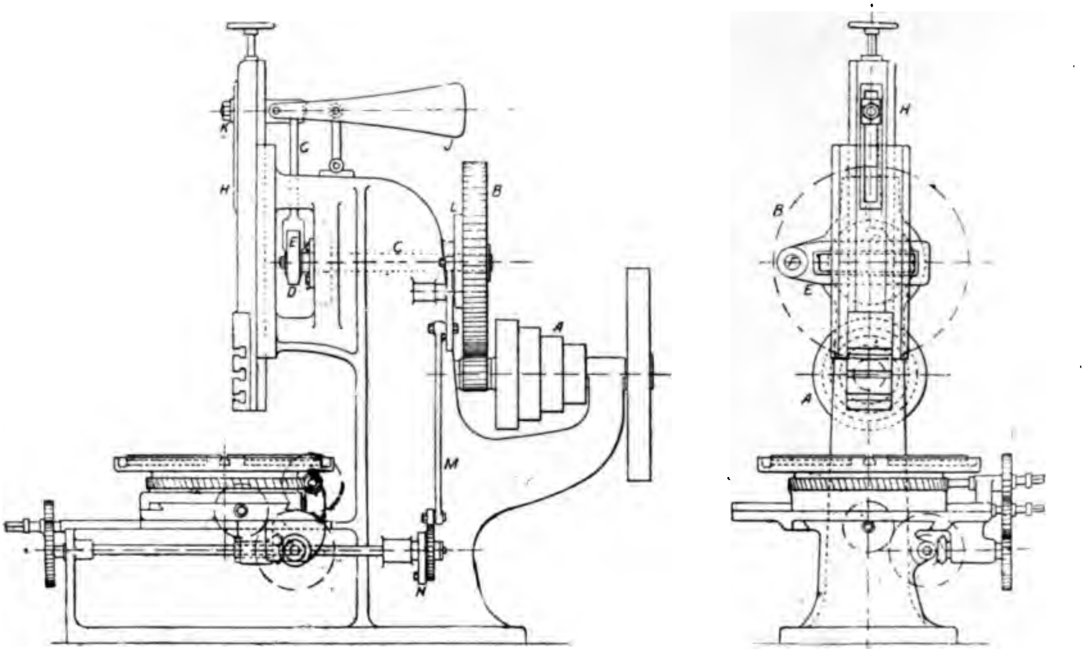


Fig. 220.—Slotting Machine.

Another form of Whitworth motion is also employed for driving slotting machines; it is shown in Vol. VII., Fig. 190, page 173, and need not be described again here. To a lesser extent the elliptic gears shown in the same article are used, the objection to them being that the teeth cannot be cut economically, but must be cast.

Fig. 221, Plate XV., shows a 16-inch stroke machine with elliptic gear drive, giving a quick return of 2 to 1. The ram is overbalanced to prevent drop, and has its tee slots set in as close as possible to reduce overhang of the tool. The drive from the cone pulley is made through two pairs of spur gears, either of which are put into gear by sliding a clutch, so giving a good range of speeds. The flywheel is formed with a rounded rim, so that it can be used to alter the position of the ram by hand. The feeds are obtained from a pair of elliptic gears, in combination with a ratchet on the bottom shaft which connects to the table gears. The circular table is 40 in. diameter, and the worm wheel turning it has a suitable number of teeth, so that by turning the worm shaft, definite subdivisions of the circle can be made, as 3, 6, 8, 12, &c. It is often the practice to put a concave brass bearing pad above the disc, as seen in Fig. 221, to rest against its rim, and resist the upward pull of the connecting rod, so that the bearing of the shaft is relieved of strain.

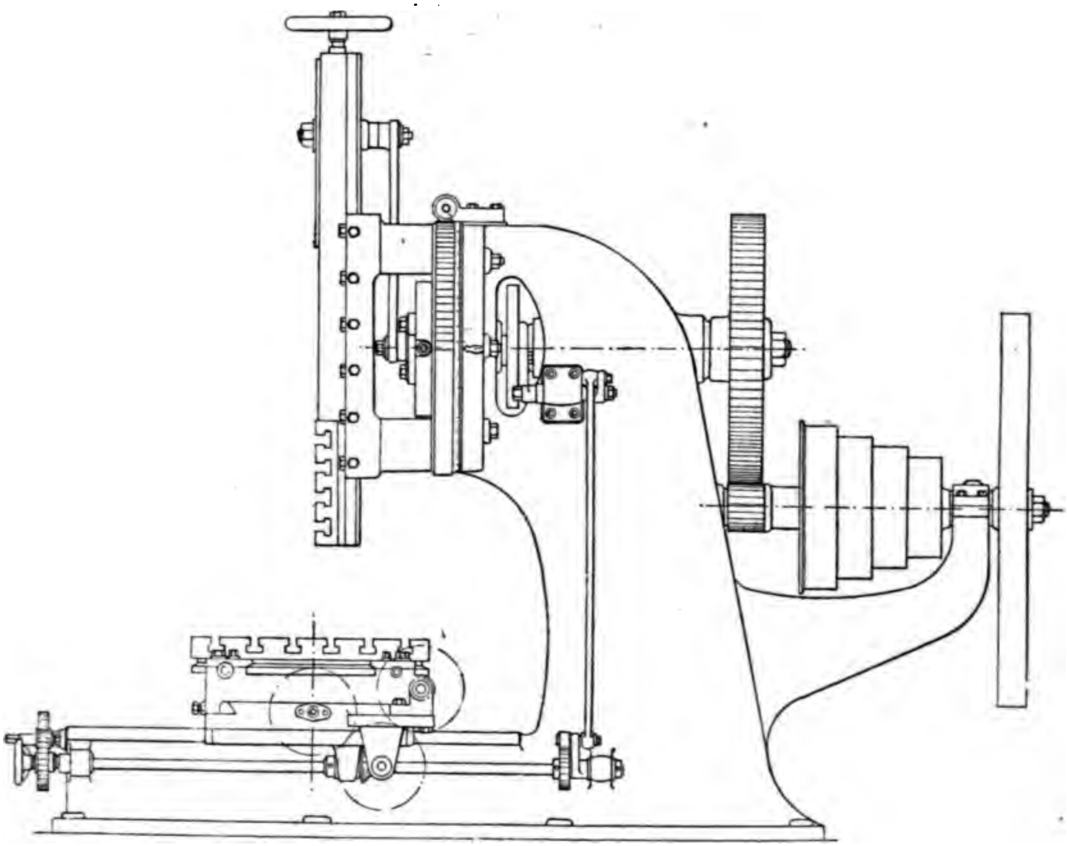


Fig. 222.—Slotting Machine.

Fig. 222 shows a French slotter, by Sculfort & Fockedey, fitted with the second form of Whitworth motion mentioned. The principal feature of interest is the swivelling head, turning upon a circular facing by means of worm gear, and secured with bolts. Graduations on the edges of the facings indicate the extent of angling.

The advantage of this fitting lies in the machine having increased capacity for angular slotting, without troubling to pack up the work on the table. The hand-wheel at the top of the ram is used for turning the screw that adjusts the sliding pivot block of the connecting rod.

Another machine with Whitworth motion of the same class is illustrated in Fig. 223, Plate XV., this being of 18-inch stroke. The principal point of novelty in this is that the ram slides in a long guide which is adjustable up and down, so that the amount of overhang of the bottom of the ram may be reduced to a minimum. This guide passes through gibbed ways at the top, and is carried back to embrace the column below, where a central rack and pinion, turned by a handle, through worm gear, provides the means for raising and lowering the guide. There is a screw within the ram for adjusting its relative height to suit the work, but instead of being worked by a hand-wheel on top, mitre gears are placed below, and operated by a handle on a squared shaft seen projecting from the face of the ram above the tool clamps. The feeds for the tables are derived from a cam groove on the face of the large spur wheel, rocking a ratchet lever, as seen. There is a mandrel in the middle of the circular table, to hold work which has a central hole.

The largest slotting machines are rack-driven on a similar principle to planers. Fig. 224 illustrates a Sculfort & Fockedey machine of 850 mm. stroke (2 ft. $9\frac{7}{16}$ in.) which is driven from an electric motor, A, at the base, geared to a large and a small pulley, B and C, which are belted up to fast and loose sets of pulleys, D and E, the first for quick return, the second for cutting. Trains of spur gears, seen dotted in the side elevation, communicate to the rack teeth on the back of the ram. The belts are shipped on the pulleys by strikers seen in the front view, these being actuated by a rotating disc, F, geared up to the driving wheels. Stop-dogs on the face of the disc are set in any required position on the circle, to strike a lever which moves the gears and levers at G. The feeds are obtained from a disc, H, geared up to the driving wheels, and rocking a rod, J, operating the ratchet box at K which is coupled up to the shaft L. It will be noted that the ram is counterbalanced by a weight within the column, attached by a wire rope to the ram.

Fig. 225, Plate XV., represents a massive rack geared slotter of 54 in. stroke. The ram is actuated by a train of spur gears worked from two pairs of fast and loose pulleys of different diameters, the belts being shipped by striking gears, as in a planing machine. Two adjustable dogs bolted to the face of the ram strike the trip levers for working the shippers. Counterbalance weights are attached by wire ropes to the ram, and the latter slides in an adjustable guide, as mentioned in connection with Fig. 223, Plate XV. A tool holder with a relieving clapper is shown in place on the ram. The feed movements are operated from the ram by the same dogs that ship the belts; these work a tappet lever which is coupled by a rack and quadrant to a vertical shaft going down to bevel gears, with a reversing clutch between. The horizontal shaft driven by the bevel gears is connected thence to the various ratchet mechanisms for operating each table spindle. Although the nominal stroke is only 54 in., the actual travel is practically 9 ft., this being available on outside work.

The dragging friction of the slotting tool on its upward stroke is often neglected, though such friction has a detrimental effect on the cutting edges. But there are a great many relieving holders used, which have a pivoted box so that the tool may give way as it rises; a spring keeps the holder just up into place so that it shall keep the tool ready for cutting at the down stroke. The machine just shown is fitted with a relieving holder, bolted to the ram, and having a small clapper box hinged at the bottom, the tool projecting out from this. Many machines embody a permanent form of clapper forming an integral portion of the ram end. Tee-slots are sometimes cut in the bottom end of the ram to hold tools projecting out at right angles, a good type for slotting certain pieces of work. Large machines also have sometimes a series of slots cut across the face of the ram right to the top, so that very long tool bars can be gripped firmly by straps. Such bars have tool points held in by set-screws at the end. Frequently two tools are set side by side on the

PLATE XV.

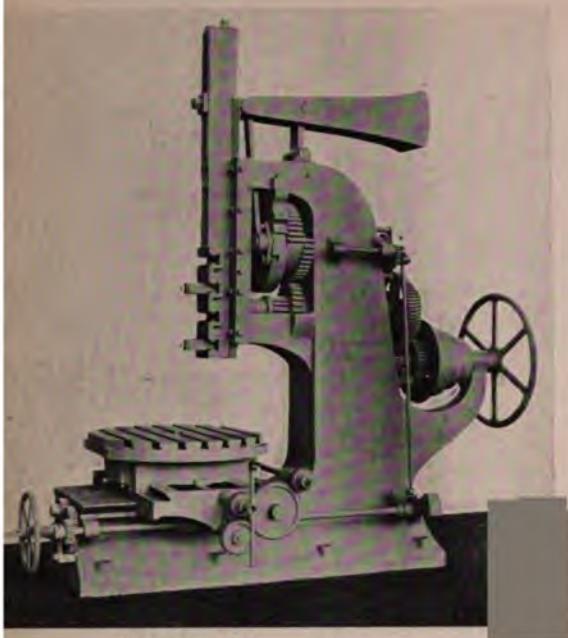


Fig. 221.—Slotting Machine.
(Thomas Shanks & Co.)

Fig. 223.—Slotting Machine.
(The Niles-Bement-Pond Co.)

25.—Rack-Driven Slotting Machine.
(The Niles-Bement-Pond Co.)

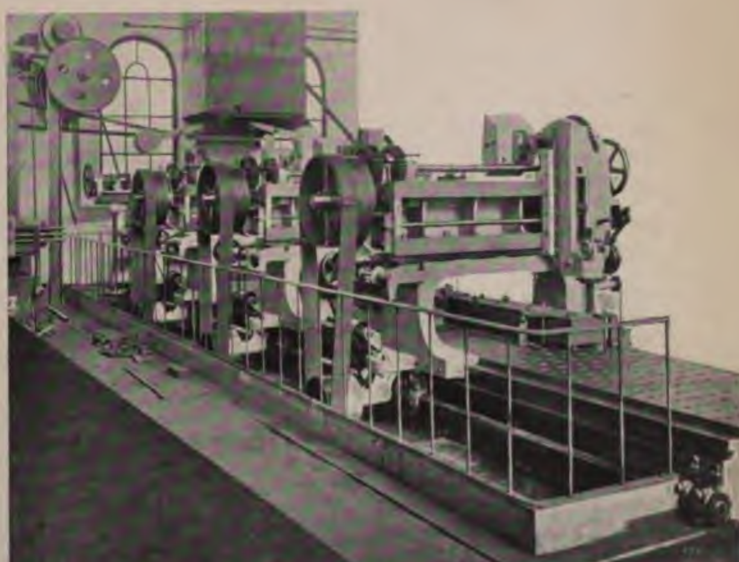


Fig. 226.—Frame-Plate Slotting Machine.
(Fairbairn, Macpherson.)

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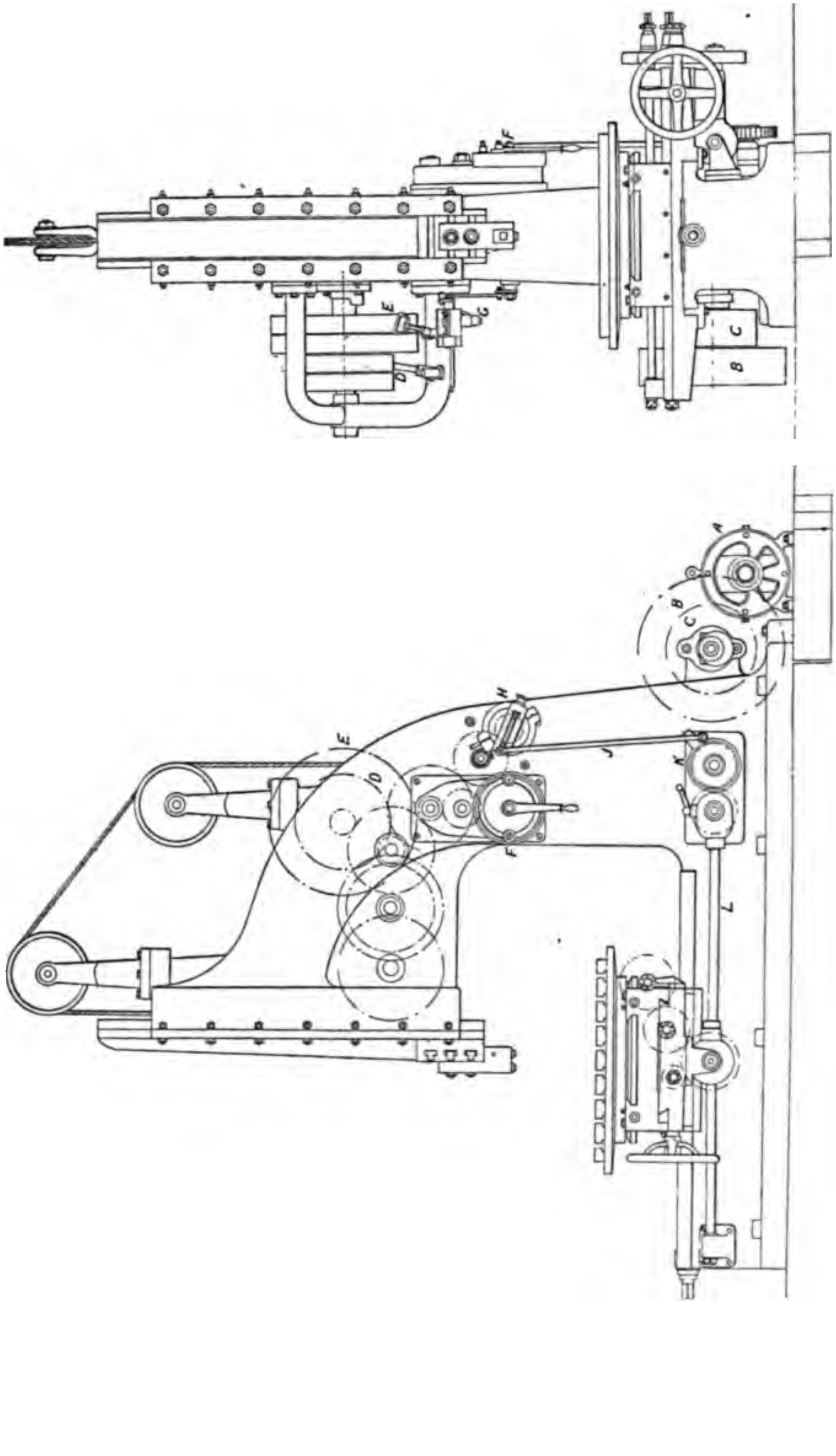


Fig. 224.—Slotting Machine.

ram, to cut on both faces of a job simultaneously, as in slotting axle-boxes, &c.

The frame-plate slotting machine is a special type employed for slotting around the edges of locomotive frame-plates, which are laid in a pile on a long table, and operated on by tools working on four or more rams. The latter slide in saddles supported in cross-girders spanning the table. Suitable feed arrangements are introduced for moving the saddles laterally, and the cross-girders longitudinally, so that the long stretches, and the internal parts, such as axle-box openings can be tooled.

Fig. 226, Plate XV., shows a frame-plate slotter in operation on a pile of plates. It has four heads, all actuated from a shaft lying alongside the bed, near the bottom, the shaft being splined to drive bevel gears, and thence the belt pulleys seen.

Slow Gear.—When a lathe or other machine spindle is being driven through back gears, it is said to be in slow gear. The term is also applied to the driving of a crane at its maximum capacity through double or treble gears.

Sluice Valve.—Sometimes termed a **Sluice Cock**, or a **Gate Valve.** Designates that design in which a disc is slid over the face of the passage way. These are used mostly for water mains and gas mains. *See* **Gas Valves.**

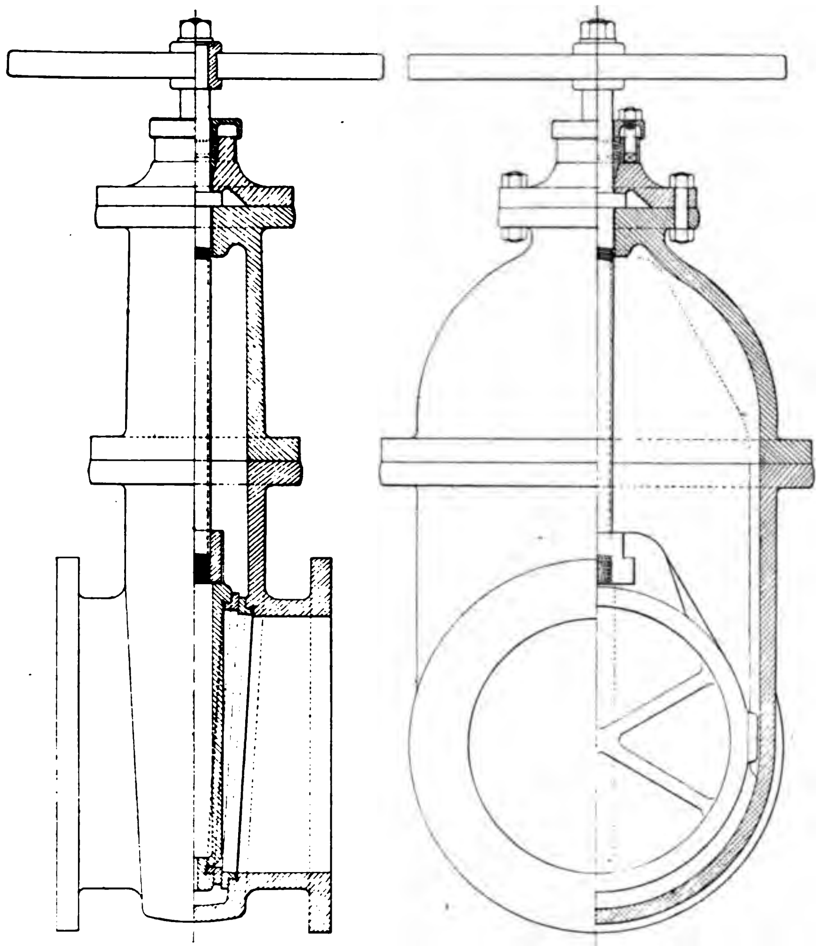


Fig. 227.—Sluice Valve.

The usual form of sluice valve is the wedge design, so termed because the sliding valve or plug is wedge shaped in vertical section, being thus self-adjusting for wear, as well as being tight when screwed down.

Little change has taken place in the design of these valves. They comprise the body, made in two portions; the lower, which contains the valve seatings or faces, and the upper, which affords the necessary space for the plug to occupy when the valve is opened fully. The two parts are bolted together through flanges. Another flange on the top portion receives the cover with its stuffing box and gland through which the spindle passes. The spindle is prevented from endlong motion by a collar entering a recess in the stuffing box. A hand-wheel on the top

f the spindle is used to turn the latter. All he lower portion is screwed with a square hread, and engages with a T-shaped nut tted into a corresponding slot in a lug on he top edge of the plug. A hole is cast hrough the middle of the plug, and bossed

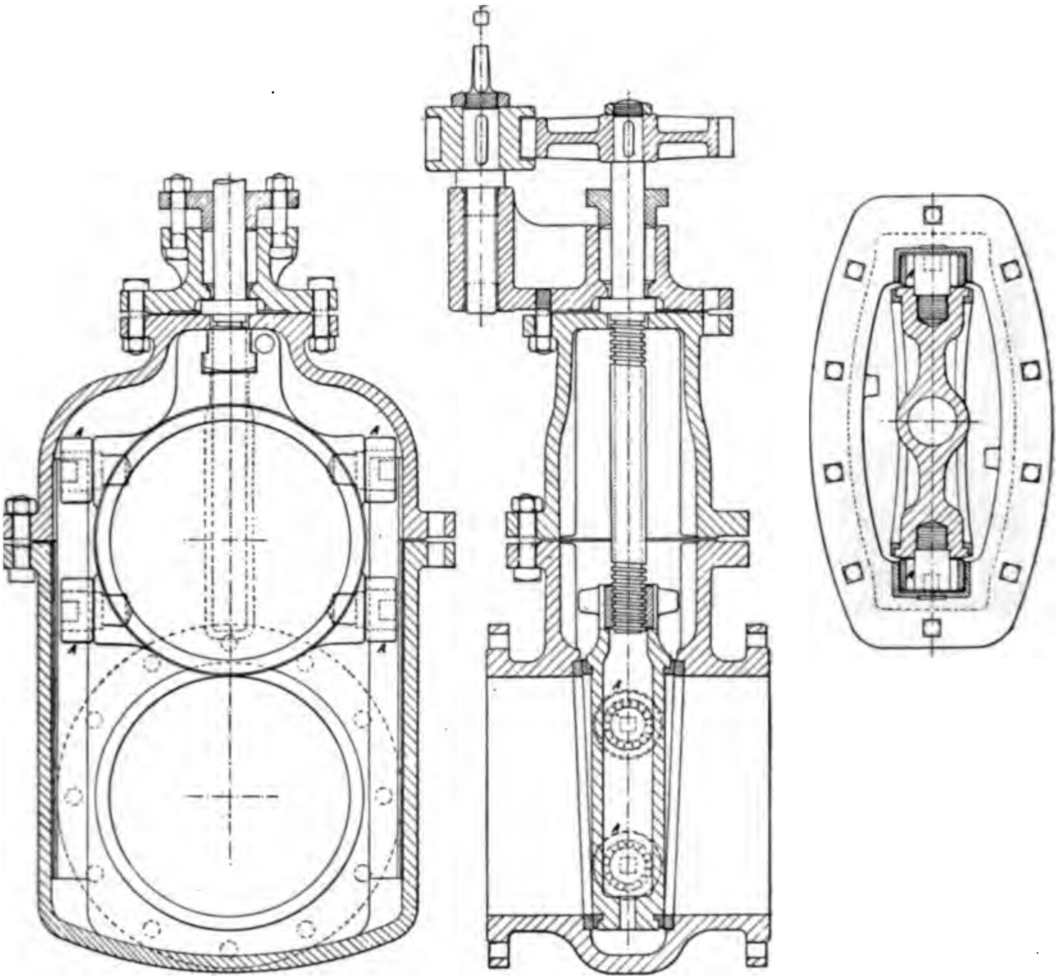


Fig. 228.—Sluice Valve, with Antifriction Rollers.

rith metal to receive the screw as the plug s drawn upwards. The faces of both plug nd seatings are fitted with rings of gun-metal. 'o steady the plug after it has been lifted clear f the facings, a rib is cast on each side, rhich slides between ways cast within the hell. In some of the best valves as now made, hese sliding edges are fitted with antifriction rollers. Sluice valves are fitted either with flanged, or socketed connections to suit requirements.

In some cases, when large mains are under high pressures, the width of a doorway has been divided into two or three separate openings, each with its own separate door. This entails some differences in the design.

Large valves cannot be screwed up and down with a hand-wheel. . A pair of gears is then used, a pinion at one side operating a wheel on the spindle. In other cases a hydraulic ram has been used, the action being direct sliding without a screw. The pressure may be

taken direct by means of a controlling lever, or an electric current may be used to operate the hydraulic valves.

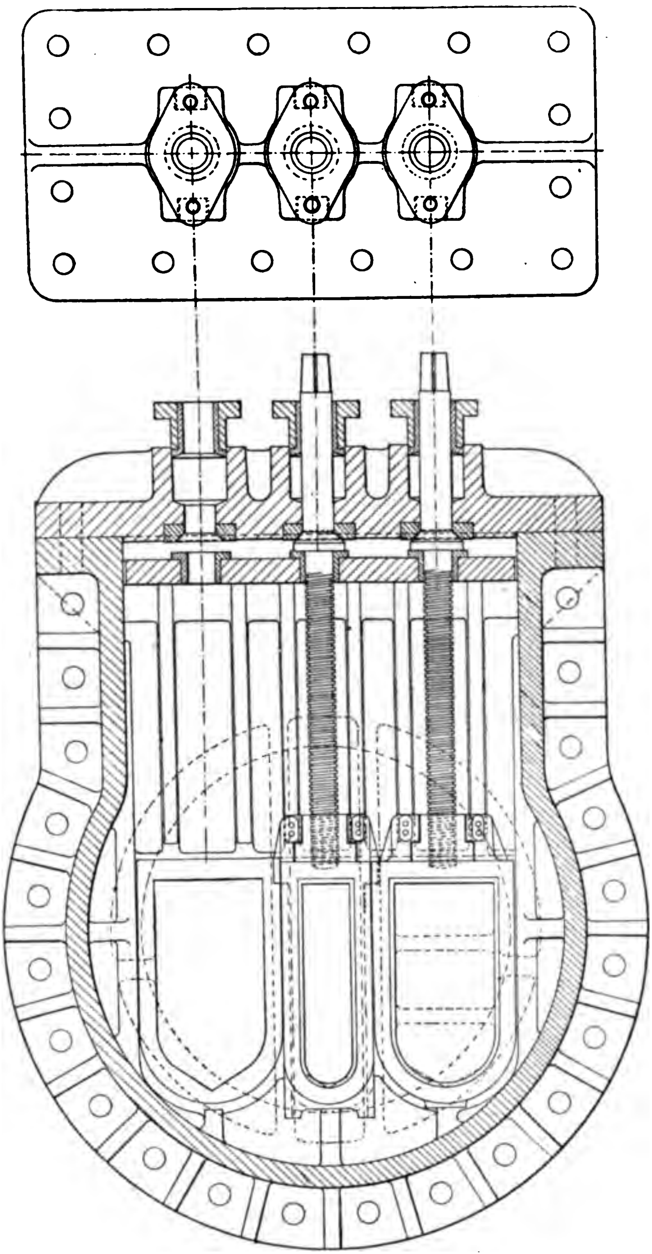


Fig. 229.—Sluice Valve with Three Doors.

Fig. 227 illustrates a wedge design of valve by J. Hopkinson & Co., Ltd., as made in sixteen sizes ranging from 2 in. to 20 in. bore, and either with flanges, and drilled to the British standard, or to the firm's long established standard. The facings are of gun-metal, and the bodies of cast iron. They are tested to 400 lb. water pressure, and are suitable for working pressures of 200 lb. water, or 55 lb. steam.

Two interesting valves are shown in Figs. 228 and 229 from the practice of Messrs Glenfield & Kennedy, Ltd. The first, Fig. 228, is of 15 in. bore, and designed for a working pressure of 300 ft. The wedge facings are of bronze. In order to render the operation of the valve easy, antifriction rollers, A, A, A, A, are placed on each side of the valve, running on planed ways, so that the work of lifting and lowering the valve is greatly lessened. The rollers themselves do not run direct on their pins, but upon a ring of rollers. The spur gears at the top afford sufficient gain of power to work the valve easily. The screw is of forged brass, $2\frac{1}{8}$ in. diameter, working in a brass tee-headed nut let into the top of the valve.

The valve in Fig. 229 differs from ordinary patterns in having three doors, this type being employed for large mains under high pressures. The present example measures 4 ft. 2 in. inside the body. The middle door is opened first, and to ensure this being done, locking snugs render it impossible to lift the outer doors while the middle one is down. The body of the valve is made in halves, united by bolts and studs, the latter being turned, to fit in drilled holes and so ensure correct register, while the bolts have square necks. The plate below the cover, which receives the bushings for the necks of the screws, is of wrought iron. The screws also have two bearings in the cover.

Sluice valves for large mains are fitted with a by-pass, the object of which is to relieve the pressure before opening the valve. It comprises a small pipe with a flanged bend at each end, bolted to the main pipes on each side of the valve. A small valve is bolted in the course of the by-pass pipe, and

is opened to make a course for the water instead of going through the main valve. The diameter of the by-passes as supplied by Messrs Glenfield & Kennedy, Ltd., are:—

	In.	In.	In.	In.	In.
Main pipe	12	15	18	21	24
By-pass -	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4

Valves of small diameter are also sometimes provided with a by-pass. They are useful when in a new district the by-pass is large enough to supply present needs. It can also be used for sounding for waste.

Slurry.—The mixture used for lining a Bessemer converter, or the clay wash used by moulders.

Small Arms.—Portable fire-arms, as distinguished from the machine guns and ordnance, and including pistols, revolvers, smooth-bore guns, and rifles.

The earliest type of gun appears to have been the hand-gun, a plain tube attached to a wooden stock, and provided with a touch-hole, at which the match was applied. The introduction of mechanism enabled the match to be brought down by means of trigger and cock to a pan alongside the barrel, the pan containing priming which when ignited fired the charge in the barrel. The next improvement was the wheel-lock, in which a piece of flint was made to produce sparks by the action of a serrated wheel, set in motion by a spring, the sparks falling on the powder in the priming pan. The flint-lock displaced the wheel-lock, its action being that of a cock which held a flint, caused to fall upon the steel pan, and by the sparks evolved, to ignite the priming powder. The use of fulminating powder caused a great change in guns; it was first applied successfully by Forsyth, a Scotchman, and eventually assumed the form of a copper cap, lined with a fulminating substance, this cap being slipped over a nipple, and struck sharply by the hammer. Previous to this, the bayonet had been fitted to guns; it was evolved from the earlier form of a dagger inserted in the muzzle.

Lefaucheux was the first to evolve a practical type of breech-loading gun; double barrels were fitted, for sporting purposes, and they were hinged so as to be thrown up to expose the bores, into which cartridges were placed. These cartridges contained the charge of powder and shot, and were fitted each with a pin, standing out laterally, and reaching to the percussion cap in the base of the cartridge; the fall of the hammer struck the pin, and so exploded the charge, driving out the shot, and leaving the empty case. This pin-fire system later on gave way to the central-fire, which is the style most in use; the percussion cap is placed over a little anvil at the cartridge base, and is struck by a striker-pin. There are also rim-fire cartridges, in which the fulminate is placed in an annulus around the rim at the base. In order to retain the cartridge case in place, it is necessary to form a chamber at the breech end, and to remove the empty cases, an ejector or extractor mechanism is employed. A hook or lever is caused to engage with a flange on the base, or a groove sunk around it, which serves as a means of withdrawal. The simple action of dropping the barrels, to open the breech, is utilised in many cases to operate the ejector mechanism.

There are two forms of bore which differ from the plain parallel; the choke bore, adopted in shot guns, and consisting of an enlargement of the bore towards the breech end, and a contraction at the muzzle. The object is to concentrate the shot around the mean trajectory. A good many variations exist in methods of choke boring by different gun-makers.

Rifling, consisting of producing spiral grooves within the barrel, serves two purposes. In the first place the bullet fits accurately on being driven through the barrel, so there is no *windage*, or slackness, a defect which prevents precision of aim; in the second place, the rotary motion imparted to the bullet greatly assists it to pursue a true course. Many styles of grooving are in use, varying from two to six in number, and of different pitches, an average being that of one turn in 10 in. With the smaller bores in general use now for military rifles, a difficulty is found in getting a lead bullet to "take" to the grooves, its softness permitting it to strip and tear up; bullets with sheaths or coatings of some harder material are therefore employed, cupro-nickel being the most favoured, while steel has been used.

The use of central-fire cartridges led to an improved method of striking, instead of the hammer; the Prussian needle-gun had a thin, long needle, which, on releasing the trigger, was impelled by a spring, piercing the cartridge-case end, and striking the detonating cap. Although this needle system possessed defects, due chiefly to the delicacy of the needle itself, it does not differ materially from the methods in use to-day; the difference is that the needle is replaced by a striker-pin of ample size to withstand the effects of hard work, without breaking, or becoming damaged. Before going into details of the different army rifles, the two different means of closing the breech must be considered; these are the block, and the bolt system respectively. The block type has a hinged or pivoted block, which can be thrown back to admit the cartridge, and then shut down or tilted up to close the breech, the end of the cartridge resting against this block, through which the striker passes. The bolt action, which has practically superseded the block, comprises a long bolt sliding behind the breech, and capable of being moved up to close the latter; the striker is carried in the centre of the bolt. A ball-ended lever standing out laterally enables the bolt to be manipulated. An extractor is attached to the bolt in such a manner that its hooked end engages with the grooved or flanged end of the spent cartridge, and extracts it from the breech, on the backward motion of the bolt.

The magazine or repeating rifle is the type with which troops are now armed; it is capable of firing a number of shots in rapid succession, the cartridges being fed from a magazine holding from five to ten; at the same time, hand loading can be done in some patterns, without using the magazine. The earlier magazines were tubular, carrying the cartridges end to end in a tube either in the stock, or underneath the barrel; the disadvantage of this plan is that the balance of the rifle is being continually altered as the cartridges are fed along, and that the filling of the magazine cannot be rapidly done. The majority of army rifles are therefore fitted with box magazines, in which the cartridges lie side by side, usually in a vertical direction, and are pushed upwards by springs as fast as they are used. The cartridges are not necessarily inserted direct in the magazine, but are handled more conveniently in packets held lightly in a steel spring clip, which is pushed into the magazine; it is but the work of an instant to put in one of these clips, and the rifle is then ready to fire a number of rounds as quickly as the marksman can aim and pull the trigger and the bolt. In those rifles fitted with a cut-off mechanism for putting the magazine out of action temporarily, a plate is slid across the top of the magazine, and hand-fed cartridges are laid on this.

We cannot give detailed descriptions here of the various types of rifles used by the great military powers, but a few notes of the principal characteristics may be made. The British type is the Lee-Enfield (short rifle), having a calibre of ·303 in., with 5 grooves, ·0058 in. deep, one turn in 33 calibres. The magazine holds 10 cartridges, and 34 rounds can be fired in a minute. The length of barrel is 25·19 in., and of the rifle over all 44·5 in.; its weight without charge or bayonet is 8 lb. 2½ oz. The weight of the complete cartridge is 415 grains.

Germany has the Mauser of ·311 in. calibre, with 4 grooves, one turn in 30·2 cal. The magazine holds 5 cartridges, and 40 rounds per minute can be fired. The total length of rifle is 49·4 in., and weight 9 lb.

The French pattern is the Lebel, the only one that retains the tubular magazine; calibre ·315, 4 grooves, one turn in 30 cal. Magazine carries 8 rounds, and with 1 in chamber, gives a rate of 9 rounds fired per minute. Total length 51·12 in., and weight 9 lb. 3½ oz.

The Russian, termed the "3-line," has a calibre of ·300, 4 grooves, one turn in 31·6 cal. Magazine holds 5 cartridges; 24 shots can be fired in one minute. Length 51·875 in., and weight 8 lb. 15¼ oz.

The Austrian type is the Mannlicher, ·315 in. calibre, 4 grooves, one turn in 31 cal. Magazine carries 5 rounds, and 30 rounds per minute can be fired. Length 50 in., weight 8 lb. 5½ oz.

Italy has the Mannlicher-Carcano, calibre ·256 in., 4 grooves, one turn in 36 cal. Magazine takes 6 rounds; 15 can be fired in a minute. Length 50·75 in., weight 8 lb. 6½ oz.

United States; the Krag-Jörgensen, with calibre of ·300, 4 grooves, one turn in 30 cal.

The magazine holds 5 cartridges, and 43 rounds can be fired in one minute. Length 48·25 in., weight 9 lb. 1 oz. A modified form has been manufactured since, with a shortened barrel, and other features.

Japan uses the "Year '30," calibre of ·256; 6 grooves, one turn in 30·7 cal. Magazine holds 5 cartridges, and 25 rounds can be fired per minute. Length 50·5, and weight 8 lb. 9¼ oz.

The initial velocities imparted to the bullets in these various rifles vary from 1,923 ft. per second in the lowest to 2,395 ft. in the highest.

There are some types of automatic rifles, such as the Browning, in which the recoil is utilised to open the breech, eject the empty case, reload, and recock ready for another shot.

Pistols.—These are used to a comparatively small extent as plain weapons, but when supplied with automatic means of feeding the cartridges they are found to exist in great variety. The revolver has a revolvable barrel, or rather cylinder, which rotates one-sixth when the hammer is cocked, and so brings a chamber opposite the barrel, this being repeated until the six chambers are emptied. In the double-action revolvers the act of pulling the trigger fires the shot, and then brings round another chamber. Automatic revolvers utilise the recoil of the barrel, which is a sliding fit in the stock portion, to perform the necessary movements. The motion of the cylinder, which has cam grooves cut around its body, provides the turning effect. The automatic pistols differ from the revolvers in having the cartridges stored in a magazine, from which they are automatically fed to the barrel; they are more compact than the revolvers, and the disadvantages attendant on the use of a rotating cylinder are avoided.

Manufacture.—The manufacture of small arms lends itself admirably to systematic production; in fact, the interchangeable system of manufacture was first founded in France in connection with small arms production, and was subsequently developed in America by Whitney. Drop forging, turning on capstan and automatic machines, profile milling, jig-drilling, hardening and tempering are all brought into service during manufacture.

The barrels are made from crucible, or Siemens steel; the Damascus barrels, used to a considerable extent for sporting purposes, are produced by coiling welded ribbons of iron and steel to form a cylinder; the resulting formation of the alternate layers of iron and steel produces a very beautiful pattern, comprising interlocking circles; when etched the iron takes a brown colour, and the steel shows up lighter. The Damascus barrels are no better for strength than the solid steel, and their only merit lies in their nice appearance.

Two methods are in use for the production of military barrels; they may be either forged to shape under hammers of the Bradley type, or rolled; the latter plan is followed at Enfield, the bar being passed through ten pairs of rolls, which reduce and taper it to proper dimensions at one heat. The breech end is then forged to shape under a hammer, and straightened by machines, and by hand. They are turned at the ends to form reference places for future operations. The ends are then faced and countersunk, ready for drilling. Half-round bits are employed, working either from one end, or two from each end simultaneously, lubricant being pumped in to clear out the cuttings. The barrel makes about 1,000 revolutions per minute. The next operation is draw-boring, with a three-cornered bit, after which the outside is rough-turned down to the taper in a special lathe, using three tools. The barrels are straightened, the bore being viewed with the barrel pointing so that a horizontal board cutting across a window pane can be seen just above the centre of the bore; the form of the triangular shadow thrown indicates to the straightener whether the bore is straight or otherwise, correction being effected by blows with a hammer. A square bit is now used to fine-finish the bore, two of its corners being kept from touching the interior by wooden spills or splines. The outside is then finish-turned, and polished, after which the rifling is done. The method pursued at Enfield is that of the single-tool or hook cutter, set in a rifling bar, which is caused to turn at the correct rate, and so produce the rifling. The hook cutter draws in automatically on the return stroke, and its feed for cutting is stopped at the proper depth automatically; the indexing of the barrel being done for the required number of grooves. Polishing follows, a lap running up and down inside

the rifling, and another afterwards revolving to finish the cylindrical portion of the bore. The rest of the operations include milling the thread of the breech end, chambering out the breech, tapping for the sights, &c.; browning is done to preserve the barrel from rust.

The other components of the rifle involve many operations which are too numerous to enter into. The wooden stocks of walnut are produced by rough sawing, and then turning to shape on a copying lathe, working from an iron former, which controls the path of the cutterhead; the recesses are cut out by revolving cutters, and the stock bored for the reception of the fastening bolt and oil bottle. All the parts of the rifle are made so that they will be interchangeable, and the assembling does not involve any alteration of dimensions to make the portions fit each other.

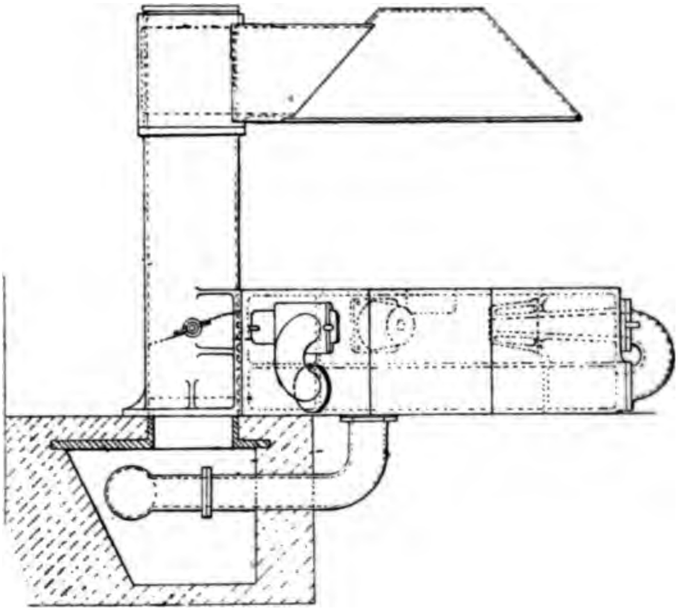
Smelting.— The reduction and extraction of metals from their ores. The work of smelting dates from a high antiquity, since articles of copper, bronze, gold, and silver occurred in neolithic times, and the existence of these metals and their alloys may be taken as conclusive proof that the art of their extraction must have been understood. Only copper, gold, and tin occur pure, and copper and tin in but small quantities. Iron was certainly known 1,000 years B.C., and was in common use before the Christian era. With regard to iron we are not in doubt as to the methods by which it was smelted, for methods which are practically identical are still practised in India, Africa, and in Spain. The furnaces used are only from 2 ft. to 4 ft. in height, by from 10 in. to 18 in. in diameter, and yield but a few pounds of iron or steel at a charge. There is one tuyere opening for blast, and another for slag and metal. Bellows supply blast, and charcoal is the fuel used. The ore is reduced by the carbon, and a lump of spongy metal results. From the same furnace malleable iron, steely iron, and cast iron can be and are produced, consequent on variations in temperature, and the proportion of charcoal and ore present. Different grades are sampled and obtained from the same charge.

By methods such as these iron and steel have been smelted for hundreds of years. The growth and present methods of smelting in the **Blast Furnace** are treated under that head. Iron could not be rendered fluid in the old furnaces, in which the product was a spongy bloom. Not until the invention of the tall furnaces was fluid cast iron smelted. The addition of a shaft to the ordinary furnace increased the draught and liquefied the iron. Hence Poole in 1676 alludes to the pig iron being taken from the high blast furnace to the open-hearth charcoal refinery. The Prussian Stückofen furnace described by Agricola was a Catalan furnace extended into a shaft, in which iron could be liquefied. The earliest known casting is a monumental slab over a tomb in Burwash Church in Sussex, which dates from the fourteenth century. Sir I. Lowthian Bell gives the probable date of the introduction of the blast furnace as between 1556 and 1618, because the work of Agricola published in 1556 has no allusion to it, and the work of Dud Dudley published about 1618 mentions mottled and grey iron, which are products of the smelting furnace. Dud Dudley's first patent for smelting iron with pit coal was taken out in 1620, and renewed in 1638. Abraham Darby, 1720-1733, substituted coke for coal, and achieved success which never rewarded Dudley. He started the Coalbrookdale Works in 1709.

Iron is more easily smelted than some other metals. Copper, tin, lead, pass through a succession of operations before their reduction is effected. The extraction of copper is a particularly complex process, comprising a succession of stages in each of which some impurities are removed, and in which various kinds of slags are produced. The fact that the use of copper preceded that of iron would seem to indicate that supplies of native copper were utilised. The smelting of tin is less elaborate. It is preceded by calcination and washing. The essential smelting is done at one stage, but subsequent refining is effected by processes of liquation and boiling. Zinc is produced by a process of distillation, taking advantage of the fact that it volatilises at about 1900° Fahr. The ores are first calcined to bring the zinc into the state of oxide. This is then mixed with coal and distilled. The oxygen

unites with the carbon in the coal to form CO_2, and the zinc vaporises and is condensed. There are several processes employed in England and abroad, the distillation being effected in cylinders or muffles. Lead is smelted both in reverberatory furnaces, and in small blast furnaces. The reactions are rather involved, including roasting to convert the ore into oxide of lead and sulphate of lead, and melting to convert the sulphur into sulphurous acid, leaving the lead in the metallic state. It takes place in successive well marked stages. The slags yield a further supply of lead.

The improvements which have been effected in modern methods of smelting are chiefly, the more complete extraction of metals, leaving less unreduced in the slags; the larger scale on which the operations are performed, and in some cases the substitution of gaseous fuel with the regenerative system for solid fuel. Details of smelting operations in the case of the commoner metals will be found treated under suitable headings.



Smith.—*See* **Smith's Work.**

Smith's Forge, or **Smith's Hearth.** — Forges are fixed, or portable, both being employed in engineers' works.

Fixed Hearths.—These are built of brick-work and iron, or of iron only. The bricks are built up from the ground, enclosing a rather large area within which the small coal or coke and fire are laid. This is necessary to accommodate large as well as small forgings. The size of a hearth is from 3 ft. to 4 ft. square. If an iron framing is used, it is of cast, or wrought iron, with legs, leaving an open space below. These occupy less shop space than the brick-built forges. In the brick-built forge the back is of bricks, but in the iron design it is of iron, and the hood is riveted to it. In the iron ones it is usual to cast a gap on the smith's side for the insertion of bars. The gap is filled up with a piece when not in use. The tue iron comes in at the back. There are two types of these. One with circulating water pipes, the other bolted to the face of a water cistern. Tue irons are made in wrought and cast iron. The water bosh and coal bunker are distinct from the forge, and located at the end in front, the coal being next the forge, and the water outside.

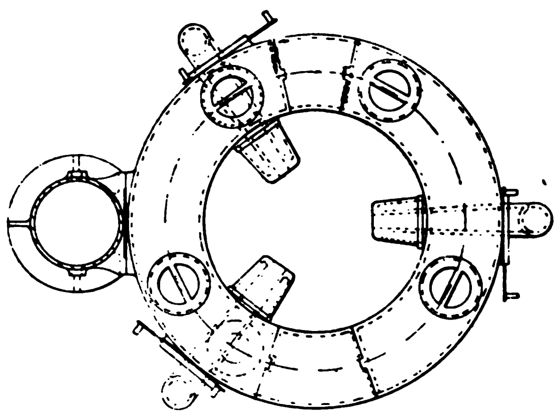


Fig. 230.—Circular Smith's Hearth.

Circular hearths, Fig. 230, are made by B. & S. Massey, for convenience of getting all round the work. The circular body which encloses

the hearth is 2 ft. through, and hollow. The upper portion is a water chamber to keep the hearth and nozzles cool, the lower is an air chamber for the blast which is delivered through three tuyeres to the fire.

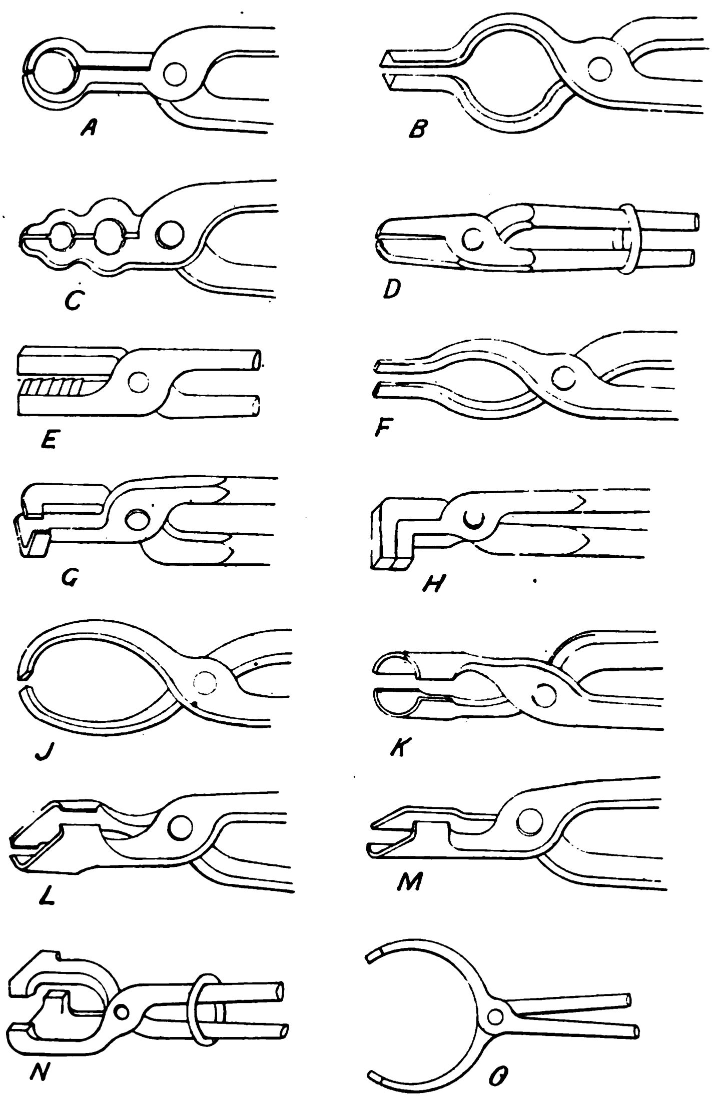


Fig. 231.—Smith's Tongs.

Portable Forges.—These are made for outdoor work, and for odd repairs, and small items done on work in course of erection in shops and sheds. They have hand bellows placed below the forge, and operated by a lever. The hearth, of circular or oblong shape, is built up of wrought iron or steel plate, and stands on iron legs. Some of these forges are fitted with travelling wheels.

Smith's Tools.—These include three main groups, the tongs for holding pieces of work, the tools for reducing and shaping, and the hammers.

As the bars and rods used by smiths seldom include more than three sections, the round, the square, and the flat, the tongs are limited to those forms which are adapted to these shapes, with variations in dimensions in each form. Cases occur in which tongs are not required, as when a forging is made on the end of a bar, and cut off when finished, but these are somewhat limited in number.

The tongs used include the following, Fig. 231 : — For round bars, the *pincer tongs*, and the *pliers* are employed. They are concave in the jaws A, or vee'd B. An enlargement behind, B, is usual to allow room for the heads of bolts, or other portions of forgings. C is a form of pliers, useful for picking up bits of small rod, and punches. A firm grip on the work is not possible by the pressure of the hands alone, except in the case of very light objects. Sufficient grip is afforded by the *reins* or *coupler*, shown at D and N, which is slid down the handles and tightened by a tap of the hammer. Tongs like B are used for square bars also, and a vee is more suitable than a concave sectional opening, being suitable alike for squares and rounds. D, E show the *flat-bit* tongs, used for flat bars; the jaws are straightforward as shown, or they are cranked like G and H, the

term *crook-bit* tongs being then applied. The jaws are either smooth, or serrated as in E. F is a form of flat-bit tongs used for light objects, and generally termed pliers. J are termed *pincer tongs*, and are used for holding bolts with heads, or stems with collars, fulfilling therefore a similar function to B. K is a form used for holding large

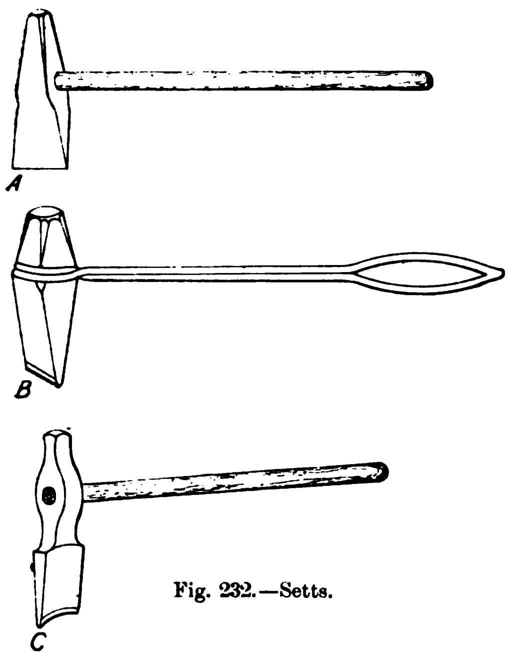


Fig. 232.—Setts.

bars. L and M are for heavy flat bars, the turned-down edges in each serving to confine the bars sideways. N is a variation on this form, but having a clearance space behind.

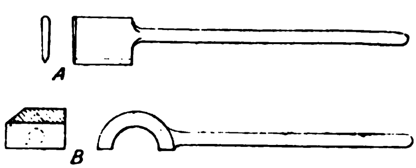


Fig. 233.—Setts.

O represents tongs employed for picking up discs of metal of large diameter, including stamping dies.

The tools used for cutting material are the chisels or setts, and those for reducing are the fullers, and swages, and in a lesser degree the set hammers, and flatters, the latter being

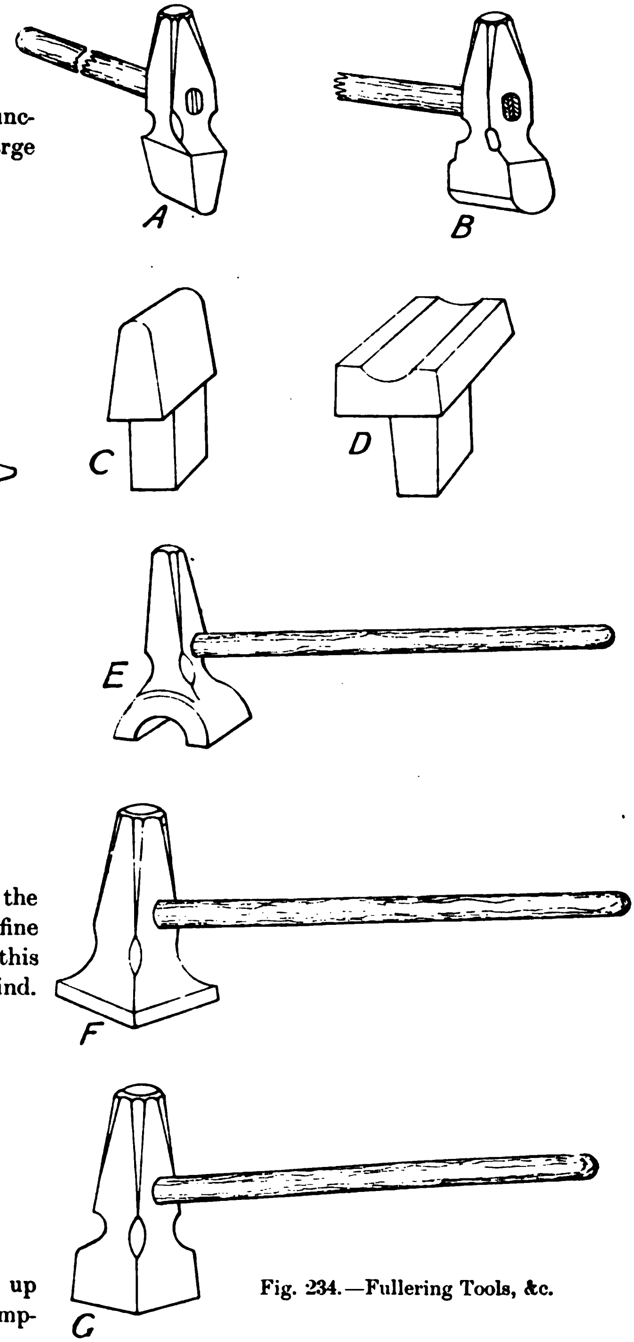


Fig. 234.—Fullering Tools, &c.

chiefly used for finishing and smoothing surfaces which have been already reduced by fullering.

The *setts* or *chisels* are keen edged for severing hot metal, Fig. 232, A, and less keen for cold

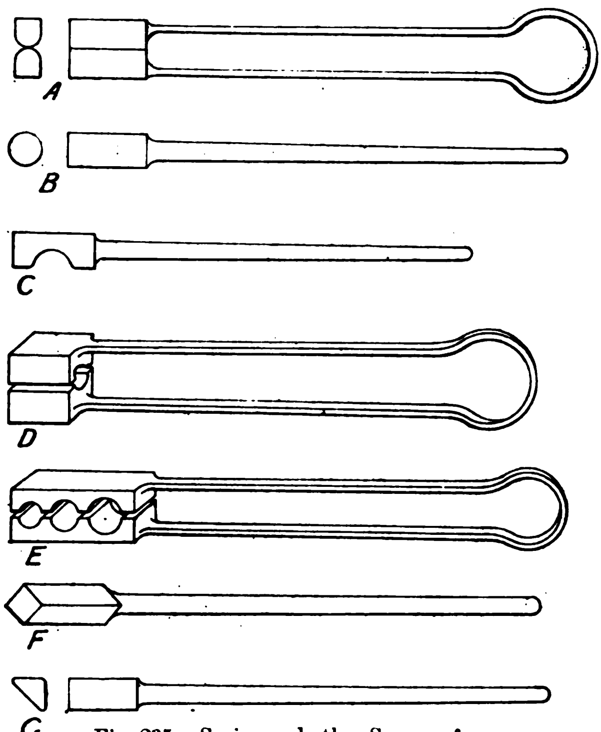


Fig. 235.—Spring and other Swages, &c.

bars, *cold* setts, B. The latter are mostly used for nicking round, after which fracture is effected by a blow. With the *hot* setts cutting is done, or reductions are effected by the removal of shavings of metal. C is the hollow, or gouge sett. These tools are handled with rigid wood, or with iron reins, or withy handles, and they are struck with the sledge. The work is laid on the anvil, but the anvil chisel or sett is often made use of for severance simply, the work being laid upon it and struck with a sledge. Work is severed under power hammers with long handled tools, Fig. 233, A being a chisel, and B a gouge sett.

The tools used for maximum reductions are grouped under the head *fullering*. They operate by a method of gradual but rapid reduction effected by individual blows on very narrow areas, using tools with convex edges. The work, or the fuller are moved along between each blow or two in relation to each other, until the larger original section has been reduced nearly, but not quite to finished dimensions. The fullers may be straight across, Fig. 234, A, B, C, or concave. C is an anvil fuller. Then the ridges are obliterated with a flatter, F, or a set hammer, G, all these tools being struck with hammers. This is the method when surfaces are flat. Circular sections are reduced with *hollow* swages, D, E, which both reduce and leave a smooth surface simultaneously. The terms fullering and swaging, therefore, both denote operations of reduction, but done on flat, and round bars respectively. Numbers of swages are handled similarly to the setts as in A, B, but others are of spring type, Fig. 235. The latter, A, D, E, include two similar halves at top and bottom united by the springy handles. But when a single swage is used, it is opposed by a bottom swage laid upon the anvil, Fig. 234, D, hence termed *top*, and *bottom tools*. The bottom, or anvil swages often include several concavities in one block. The *swage block*, Fig. 236, is a most useful appliance. Its edge is recessed with a number of concave and angular grooves covering a large range of sizes, each of which is a bottom swage. The body of the block is pierced with a number of square and

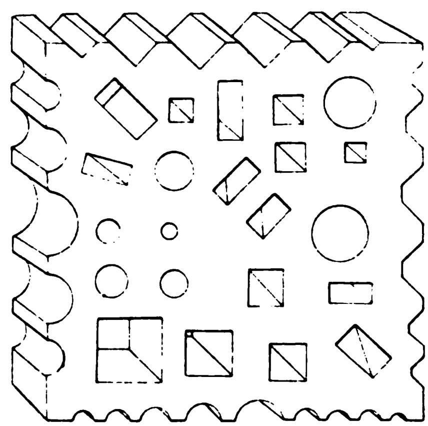


Fig. 236.—Swage Block.

round holes which are used for bending bars in by leverage.

In Fig. 235 any of the tools can be used under the steam or power hammer, and some are

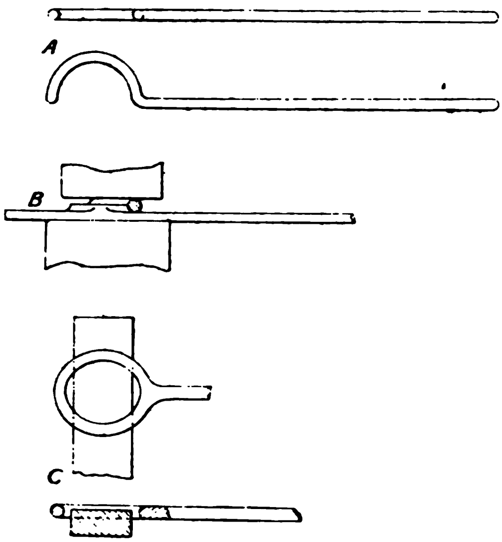


Fig. 237.—Bossing Tools.

made specially for that work. Thus B is a top fuller used for rapid reduction; C is a top swage alone; F and G are used for making scarfed joints for welds more rapidly than the work could be done on the anvil. In Fig. 237 two special power hammer tools are shown: A is one used for bossing shallow bosses; B shows it in use between the tup and anvil; C is another tool used for the same kind of work. A gap gauge is shown in Fig. 238,

Fig. 238.—Gap Gauge.

employed for measuring work while hot. Fig. 239 is a scrape for cleaning the scale off forgings. Fig. 240 is a common punch, made

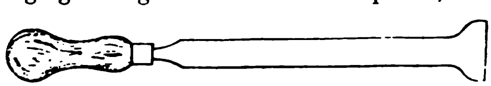


Fig. 239.—Scrape.

in the various sections shown below. In Fig. 241, A is a bent bar used for setting or twisting, or taking the set out of forgings in course of formation; B is a bar used for carrying long rods and forgings about. Mandrels are shown in Fig. 242, A, and B, on which rings are welded up and corrected. Fig. 243 shows the method of bending a ring on a bending

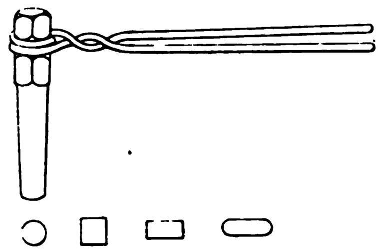


Fig. 240.—Punch.

block. Long-handled calipers, used by smiths, are shown under **Caliper**.

The hammers used are sledges, which range from about 10 lb. to 15 lb. in weight, and the small hand hammer used by the smith for light setting, and welding, and as a pointer to indicate to the hammerman or drummer the

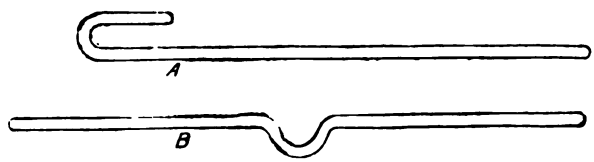


Fig. 241.—Smith's Tools.

locations at which blows are to be given. They are all handled with ash handles. The *set hammer* is not a hammer proper, because

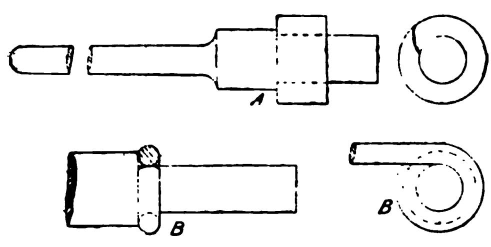


Fig. 242.—Mandrels.

it is struck by the sledge. It belongs to the group of flatters, Fig. 234, G, and is used for setting down shouldered portions.

Smith's Work — Smith.—The smithy, boiler, and plating departments have some things in common, notwithstanding they are distinct shops and trades, that the men employed in them are distinct types of craftsmen, and that the nature of the operations performed greatly differs in character.

Taking the matters which are common to

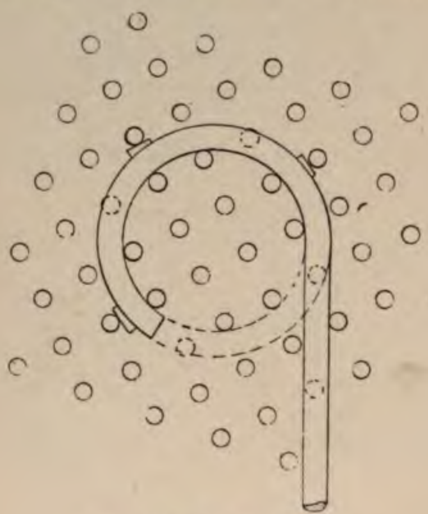


Fig. 243.—Bending Ring.

each, the materials used are identical, or very similar in each department. They consist almost wholly of wrought iron, and the various steels, the mild steels chiefly, and in a small degree temper steels. Many of the operations at the forge are similar; as drawing down, upsetting, and welding. Some of the machinery is common to each, as hammers and saws. Many of the small or forge tools are identical, and so on. Matters which are dissimilar, and specially characteristic in greater or less degree of each department, are these—bars, rods, and flats are almost the only sections used in the smithy. In the boiler shop and plating department, bars and rods are employed to but a limited extent. Plates, flats, sections such as angles, tees, channels, &c., and rivets predominating. This involves great differences in the nature of the work done, and in the machinery used, so that there is comparatively little work done at the anvil, but much at machines, as shears, punches, rolls, &c. Such work as is done at the anvil is usually different from smith's work, consisting chiefly of bending and welding sectional forms which are more troublesome than similar work done on bars and rods. In boiler work there is much of a special character done, such as flanging and rolling, staying and tubing, and the methods of performing these operations are modified with every type of boiler made, involving special machinery and special rigs-up. Die forging, so common in the smithy, is practised to a limited extent only in the plating department, and scarcely at all in actual boiler making, though it is used in the manufacture of some parts of the fittings and mountings. In the largest works each department will be subdivided suitably for the production of light and heavy work, and for specialties.

The work of the engine smith, working at the anvil alone, involves a high degree of technological skill. There are, however, comparatively few shops now in which anvil work is not assisted by power hammers, and dies. In some firms, again, most of the forgings are stamped wholly or nearly entirely in dies, and the trained smith is not then required. *See* **Forging, Forging Dies.**

The smith works in steel, and iron. The latter is still preferred when welding has to be done, but steel is suitable for nearly all other work. Both materials are supplied in rounds, squares, and flats of sizes suitable for the work of the shop. From these all conceivable shapes are produced by the operations of drawing down, upsetting, bending, welding, and punching, with or without assistance from dies.

The difference between iron and steel from the point of view of the smith is, that the first is fibrous, the second is not. Direction of grain must be taken into consideration in the first, because short fibre is weak, and liable to rupture at 5 or 6 tons per inch less stress than in the longitudinal direction Neither is this the whole difference, for inferior iron may have cinder interspersed in layers actually separating the metal, a condition termed *spilly*. Iron of this kind needs to have much work done upon it at a welding heat to expel the cinder, and unite metal to metal. These facts explain why

less punching and opening out of metal can be done in iron than in steel, the alternative in iron being bending and welding. They also explain why more bending is done in iron, and more welding than in steel, in which cutting and shaping may be done in any direction.

A very important principle to be observed in forged work is that sharp nicking, and abrupt alterations in form are to be avoided if maximum strength is to be retained. A reduction from a larger to a smaller section is not made by cutting, if fullering is practicable. This is of more importance in the fibrous iron than in steel. Nicking severs the fibres, fullering causes them to flow from one section to another. So that if a longitudinal section were made of a fullered bar, the fibres would be seen to be continuous. Smithing is thus a moulding process in the main, and cutting tools, except for severance, are used but slightly.

The methods by which the smith works are varied widely with different conditions, and the ideas of different men. Still, there are broad principles which control these diverse methods.

When differences in dimensions occur in proximity, alternatives are drawing down, upsetting, and welding. Just which should be adopted depends on relative differences in dimensions, shape of the forging, and with regard to welding also, whether iron or steel are being used.

If there is little disparity in size between adjacent sections, and if lengths are not excessive, drawing down is the readiest method to adopt. It is quickly done either with fullering tools or swages, or under the power hammer. A much larger amount of reduction can be done under power hammers than with anvil tools. But if articles are of great length, welding is the alternative. An eye, for example, will be welded to a long tension rod, while a valve bridle may be bent in one piece with its rod. A collar will be welded on a long rod, while a short bolt has its head and shank in one piece. An eye having a large hole and little surrounding metal is bent and welded if made in iron, but it would be stamped out in steel. A steel eye would not as a rule be considered safe if forged separately and welded to a steel rod, as it would be if made in iron and welded to iron. Upsetting is only suitable for local enlargements of no great length or diameter. Its principal value is in enlarging ends for welds, and in providing metal for collars of small dimensions. If collars exceed about twice the diameter of a shaft, and a length equal to diameter, they are better made as rings, and welded round the shaft. Upsetting is also necessary when bars have to be bent round quick curves. Its amount is not great, being only required to provide extra metal to counteract the extension and attenuation of the fibres on the outer portions of the curve.

The forging of small stamped work is a highly important section of smithing in many modern shops. Without the adoption of this device many articles could neither be done cheaply, accurately, uniformly, or expeditiously. By its adoption a good deal of laborious hand forging is saved, and very often some machining. Moreover many articles which would otherwise be cast in malleable iron, steel, or even gun-metal, are better made by forging. To carry the system out on an extensive scale requires a rather expensive stock of dies or stamps. Nevertheless the system is better if allowed to develop naturally, in which case the outlay for any given year need not be heavy. Generally, too, work of this kind should be restricted to two or three hands, who then acquire a facility in the preliminary preparation of the forgings, and in the manipulation of the dies. Generally, too, the smith will design his own dies, because he knows better than any one else the precise nature of the difficulties which are met with in the stamping and delivery of the forgings. These often necessitate a construction, the reasons for which would not be obvious to any one whose experience in these matters has not been of a practical nature.

Smithy.—The shop in which the operations of forging are carried on. With few exceptions, it is an oblong building, constructed similarly as regards walls and roof to the other buildings in a works. Forges are ranged down one side if the shop is narrow, down two opposite sides if it is of good width. With a single line of forges, the opposite wall and the ground adjacent are occupied with stands of iron bars, and with odd ends, or dies on shelves. If both walls are

utilised for forges, the central area of the shop, or an end are reserved for storage. When machines are employed they are located about the centre of the shop adjacent to the forges which require them most.

The pipes which supply blast to the forges are brought along about level with the ground against the wall, and are brought in at the backs of the forges. A handle comes from the throttle valve to the side where the smith stands. The forges are built of brick, with a central space for the fire. Sheet-iron hoods above conduct the smoke into the chimneys, built of brick, and standing out from the wall. In front of the forge is a bunker for small coal, and a water bosh for damping the coal, and for cooling and hardening work. Pipes laid underground convey steam, compressed air, or pressure water to the hammers and machines ranged down the middle of the shop.

Anvils are stood in front of the spaces between forges, standing out beyond the front of the forge, to leave room for the smith to manipulate the work between the anvil and the forge, but not encroaching much on the clear shop area. Adjacent is the swage block, and often an upsetting block sunk in the floor. Racks for tools occupy the wall areas between forges.

The machine section of a smithy bears very different relative proportions to the number of men and fires in different shops. In ordinary smithies, *i.e.*, not stamping shops, the principal machines are the hot iron saw, the Ryder forging machine, and power hammers, either of steam, or some form of drop type. These must not be far from the forges. The hammers may number one to every three or four forges. They must be proportioned in power to the nature of the work done, and will be of different powers at various parts of the shop, corresponding with the light and heavy forgings. Cranes are required also. A man handling the lightest articles requires no aids from power. But for articles exceeding a few pounds in weight, a swinging horizontal jib, pivoted to the wall, and carrying a fixed pulley is required. For heavier jobs, a pair of blocks may be slung from the jib. For work exceeding about half a ton, a regular crane is necessary for rapid handling. It is still a horizontal jib crane, but fitted with a travelling jenny worked from a winch bolted to the wall, or from regular gears attached to a pivoted post to which the jib is attached. Or one of the light hydraulic or pneumatic cranes is suitable. For heavy forgings, massive jib cranes are built resembling those employed in foundries.

Heavy, and light work are handled in general engineers' smithies. Either may predominate in some shops, in others the two may be present in about equal or unequal degrees. This distinction entails differences in methods of handling, both in regard to machines, and in location of work. Heavy and light articles require machines and appliances of different powers and sizes. For this reason the two groups of work are kept separate in different areas, or in distinct shops.

Further, the methods which are adopted in light and in heavy work differ, or should differ if economy is regarded. Dies are of much greater value in the first than in the last named. The question of their employment is one not altogether dependent on size, or on numbers off, though each condition is of great importance in helping to a settlement. For though forgings may be fairly heavy, and too large to be stamped wholly, yet portions may be often finished economically in dies after having been brought approximately to outline under the power hammers or on the anvil. In the case of light forgings, a small number may be stamped with advantage, but so much expense is not put into the dies as when large quantities are ordered.

Lighting should be ample. Windows can be inserted in walls between forges above the tool racks. Or a ridge roof may give enough light by inserting enough glass. Or a sawtooth roof will be suitable. Tracks may be laid down the shop for light or heavy work. They save a lot of carrying, not only of forgings, but of materials, iron, steel, and coal.

Fig. 244, Plate XVI., shows the interior of the smithy of Messrs Mather & Platt, Ltd. It illustrates well the arrangement of hearths, anvils, steam hammers, and cranes, and needs no explanation.

A shop of a different class is represented in Fig. 245, Plate XVI., that of the Birmingham Small Arms Co., Ltd., in the steam-stamp

Fig. 244.—Smithy of Mather & Platt, Ltd.

Fig. 245.—Die-Forging Smithy of the Birmingham Small Arms Co., Ltd.

To face page 226.

department. These stamps are employed for the lighter classes of objects, while the steam hammers in the next aisle are used for heavier pieces. Light swinging grinders, one of which may be seen in front of the foremost steam hammer, are used to trim the forgings; the grinding wheel is driven by a belt from a pulley at the articulated end of the arm.

Smoke, Smoke Prevention.—The purpose of a combustion furnace is to produce heat by the chemical combination of two elements—carbon and oxygen. Unfortunately it is not possible to exclude the interference of other elements. Our source of oxygen is the atmosphere, which consists of 23 parts of oxygen to 77 parts of nitrogen, and this latter gas being chemically inactive, reduces the temperature. Fuels also, solid, liquid, and gaseous, consist of carbon and hydrogen mixed with mineral matter—which is left behind as ash. For the complete combustion of 1 lb. of carbon, $2\frac{2}{3}$ lb. of oxygen would be required, and the heat generated would equal 14,647 B.Th.U. Using air, however, as the source of oxygen, a weight of 15 to 25 lb. is required in theory per lb. of fuel, and the action of the other elements mentioned, in reducing temperature, gives an actual furnace temperature of 2,500° to 3,000° instead of the ideal 18,440° Fahr.

The chemical bodies comprised in smoke are carbonic acid, carbonic oxide, oxygen, hydrogen, nitrogen, and solid carbon in a finely divided state held in suspension in the gases and in steam. The finely divided carbon does not become deposited until the temperature lowers, and that occurs against the sides of boiler flues and chimneys. The carbon is deposited from hydrocarbons, the carbon appearing as black smoke, and the hydrogen remaining free. Burning pure carbon even with an insufficient supply of air will not produce smoke. Black smoke issues from a boiler chimney immediately after the throwing of a fresh charge of coal upon the fire. What happens is this: When the green coal comes into contact with the incandescent mass on the fire-grate, hydrocarbons are distilled off at once. If sufficient oxygen to cause the complete combustion of these hydrocarbons is brought into contact with them they will burn on the grate. If not, the unconsumed portion will pass on to the chimney. Then, if rapidly cooled, the carbon becomes deposited as black smoke, and the hydrogen remains free. The loss due to black smoke is not nearly so great as has generally been supposed, not exceeding at the outside 1·5 per cent. It is quite possible that colourless smoke may involve greater loss even than black smoke, because it may contain carbonic oxide. This, too, is the most poisonous of the products of combustion.

The smoke problem, then, is a problem of temperature. When fresh bituminous coal is placed on a fire it begins to give off volatile hydrocarbon gases—the green unburnt particles of carbon loaded with tarry matter seen rising in domestic grates. These hydrocarbon gases are, however, combustible, and ignite if they pass into a sufficiently hot zone, producing CO_2 and steam. Any chilling of these ignited gases against cold surfaces results in the deposition of soot, and the emission of black smoke. It is essential, therefore, that additional air should be admitted immediately after each stoking, to mix with these hydrocarbon gases (which are driven off in two and a half to three minutes after firing), and also that this mixture of air and combustible gas should be maintained at a sufficiently high temperature to ensure combustion. A temperature of 650° to 700° Cent. is necessary to ignite these gases. Provision must also be made to avoid the cooling of the flames and consequent production of the black smoke just mentioned. This is ensured by lining the interior of furnaces with fire-brick, which is a bad conductor of heat, and by the provision of fire-brick arches serving to baffle the gases before they reach and are cooled by the boiler tubes. The construction of an ideal furnace, then, must be such as to admit of an ample draught of air (through the furnace door, grids, or grates) to mix with the hydrocarbon gases, and also protective fire-brick lining, &c., to retain sufficient heat for the combustion of these gases.

Both excess, and deficiency of air produce smoke. Excess of air means that an extra volume of gas has to be heated, and heat consequently lost up the chimney; while an insufficient quantity leads to imperfect combustion, waste of fuel passing away in the

form of CO. Where a lofty chimney is impracticable, air is forced through the furnace by a fan, drawn through by the action of a jet of exhaust steam, or by means of other devices. *See* **Chimney, Forced Draught, Induced Draught.** Yet even with ideal conditions, bad stoking will cause smoke, and consequent loss of fuel and heat, while scientific stoking with a bad furnace often produces smokeless combustion. Spreading large quantities of fuel over the surface of the fire is certain to produce smoke, since a great amount of heat is rendered latent during the conversion of the solid into a gas, and the temperature consequently falls below that necessary for the ignition of the escaping gases. Two methods are employed to obviate any such loss in temperature—(1) side-firing, and (2) coking.

In side-firing the fresh coal is heaped first on one side and then on the other, so as to maintain one-half of the fire always in a state of incandescence. In coking, the fuel is placed near the door, so that the liberated gases pass over, and are burnt by the heat of the incandescent portion. When thoroughly coked the fuel is spread over the fire, and a fresh portion of fuel heaped in the front part of the fire. Various successful mechanical appliances have been invented to take the place of the human and fallible stoker, and these are dealt with at length under **Mechanical Stokers.**

Gas Producers, of course, provide a means of smokeless combustion of fuel. The spraying of fuel with chemical solutions evolving oxygen has been resorted to; while powdered coal blown into the furnace with a sufficient volume of air also ensures complete combustion.

The degree of intensity of smoke emitted by a chimney is estimated by comparison with a series of scales. These are squares of paper having a number of lines ruled at right angles across their surface, and when placed at a distance from the eye the individual lines are indistinguishable, and the charts present more or less grey surfaces. Of the six comprising the series, No. 0 is white, having no lines, and corresponds with "no smoke"; No. 5 is entirely black, and indicates "very black smoke"; No. 1 is ruled with black lines 1 in. wide, adjacent to spaces 9 in. wide, denoting "light grey smoke"; No. 2, "dark grey," has black lines 2·3 in. wide, and white spaces 7·7 in. wide; No. 3, "darker grey," has black lines 3·7 in. wide, and white spaces 6·3 in. wide; No. 4, "black" smoke, has black lines 5·5 in. wide, and white spaces 4·5 in. wide.

The degree of intensity of smoke emitted at the chimney top is identified by comparison with these charts, and tests are recorded on plotted diagrams in which six horizontal lines represent these smoke shades, and the vertical lines represent hours by intervals of five minutes.

It is, however, quite possible that no smoke may be emitted from the chimney and yet combustion be very far from perfect. The absence of smoke may be due to an excess of air which allows abundance of oxygen for combustion, but owing to the excessive volume of gas to be heated the temperature in the flues is too greatly reduced. Or again, though no visible smoke escapes from the chimney, invisible gases—carbon monoxide and unaltered hydrocarbons—may pass off, either owing to a deficiency of air in the furnace, or to an insufficiently high temperature. Smoke charts alone, then, do not, by any means, tell the whole story, and various other means and apparatus are employed to indicate the degree to which conditions of perfect combustion are approached. The interior of the furnace is inspected through a coloured glass—generally of a violet blue tint. Unburned gases viewed through such a glass present a dark brown appearance, gradually becoming transparent as they enter the area of perfect combustion. The speed of the draught is measured with an anemometer, consisting essentially of a U-shaped tube half filled with water, and one end of which is placed about a couple of feet into the flue, the pull of the chimney being measured on a scale. Temperatures are measured by mercury thermometers of a special type, or for very high temperatures, by water or electrical pyrometers; samples of waste gases are taken and tested for carbon dioxide, carbon monoxide, and oxygen.

Smoke Scales.—*See* **Smoke, Smoke Prevention.**

Snap Flask.—A moulding box which is hinged at one corner, and fastened with a key or snap at the opposite corner. The object of

this is to permit the removal of the box from its mould, so that the box can be taken away, leaving the mould on the floor for pouring. Very few boxes are therefore required, being limited to those which are in service for actual moulding.

The use of snap flasks has greatly extended of late years especially in American foundries. Though their utilities are limited by dimensions and class of mould, yet within those limits they are of much value. They are not suitable for work requiring boxes of more than 12 in. or 15 in. square, because beyond those dimensions the sand would not hold together. The only reinforcement which it has is an iron ring or rings rammed in top and bottom parts. The top is loaded with a couple of weights to prevent opening of the joints. The box parts are made of wood, with fittings of malleable cast iron.

Snap Gauge.—*See* **Caliper Gauge.**

Snap Head.—*See* **Rivets.**

Snatch Block, Fall Block, or **Return Block.**—The pulley or pulleys with their connections round which the hoisting chain of a crane is carried to gain power. A single fall of chain from the overhead pulley carrying the hook at its end provides for lifting at the same rate as that of the drum, with no further increase in power. But when the chain passes round a pulley the rate of lift is halved, and the mechanical gain or power—neglecting the effect of friction—is doubled. The load is also divided between two falls of chain, so that the size of the latter is lessened, with increase in flexibility. The principle is carried still further. Cranes below 4 or 5 tons' power lift on a single chain. But while cranes from about 4 or 5 tons' power are fitted with a single pulley, those of from about 15 tons have two pulleys, while for the highest powers the number of pulleys is increased still further. The pulleys at the jib head, or on the crab must be equal in number to those in the fall block. The length of chain or wire rope will have to be increased to correspond with the added lengths due to the extra pulleys and falls. The stresses in the jib and tie rods are modified.

The device of attaching snatch blocks to a crab for increasing power is applied also, though in a different way, to traveller crabs. Only for the lightest loads is the lift on a single chain. A two-part chain with a snatch or return block is the first departure.

The employment of a snatch block on a traveller crab has the same effect as on any other form of hoisting machine. The machine is capable of lifting twice the load, though, of course, at a corresponding loss of speed. It is then necessary that one end of the chain shall be looped over a loose pulley on the crab. A pulley or pulleys, therefore, according to the number of bights in the chain, are suspended in the crab, forming with the snatch block the essential combination seen in the common movable pulley blocks. The pulley or pulleys are slung in a wrought-iron strap, which in turn is suspended from a pillow block on the crab. This is generally a casting made to bridge the crab cheeks, or bolted to a cross girder bridging the cheeks at the top. As powers increase, four-part, six-part, and even eight-part chains are used. The pulleys are divided between the snatch block and the crab. In most instances there is one lead off from the barrel, but in very heavy machinery there are two, the chain or rope coiling from the ends of the barrel towards the centre. For heavy loads two drums are frequently combined, the bight of the chain depending from both.

The pulleys are cast in iron or steel, and if they carry wire rope, are turned in their grooves. They run loosely on a pin which passes through the cheeks between which the pulley or pulleys run, and their bosses bear against boss facings on the cheeks. Distance pieces and bolts maintain the cheeks at the correct distance apart in two places, about on a level with the pin. Below they are kept apart by the swivel block of the hook. When there is more than one pulley, intermediate plates are fitted, each confined by distance pieces. The cheeks are usually of forgings, or plated, seldom of cast iron, though they are sometimes so made in the cheaper and smaller cranes. The hook swivels either on a pin, as is usual on the lighter cranes, or on races of balls or cones in all the heaviest. In very heavy cranes provision is made for slewing the block by worm gear. As might be expected, there is considerable variation in the designs of these blocks, which vary with dimensions, and with grade of workmanship.

A very common design of block is made with skeleton cheeks which are forgings, used for cranes from about 5 to say 10 tons. Cutting of plates is avoided, but at the expense of smithing. The cheeks, in iron, are formed by welding the pieces to the tee form, or by cutting and opening out, or they can be stamped in steel, or they can be neatly finished by stamping, if in iron. The holes are drilled from a sheet-iron templet. The distance pieces are castings, or they may be good work. The hook is carried in a block which permits it to swivel in the vertical and horizontal planes. The hook has a stem turned on it which passes freely through a hole drilled in the block. A cotter with a deep countersink receives the end of the stem, which is riveted over into the countersink. Or a nut may be used. Thin washers are interposed, having oil grooves. The block is turned with a pin at each end, through which split pins pass, each in front of a washer. The hook, therefore, swivels in its block, and the block in the cheeks.

Fig. 246 illustrates a simple form of block with plated cheeks. It has two distance pieces, and the hook swivels only in a vertical axis. In this as in all plated blocks, whether large or small, the plates have to be stiffened with forgings riveted down the outsides, and

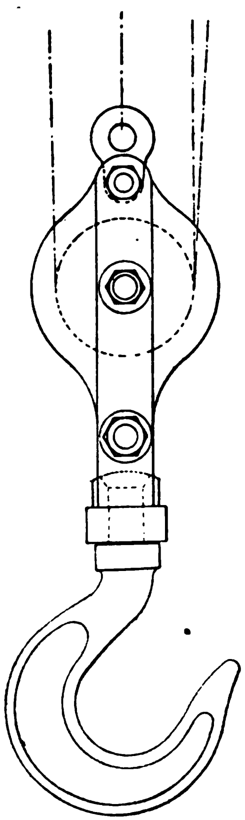


Fig. 246.—Snatch Block.

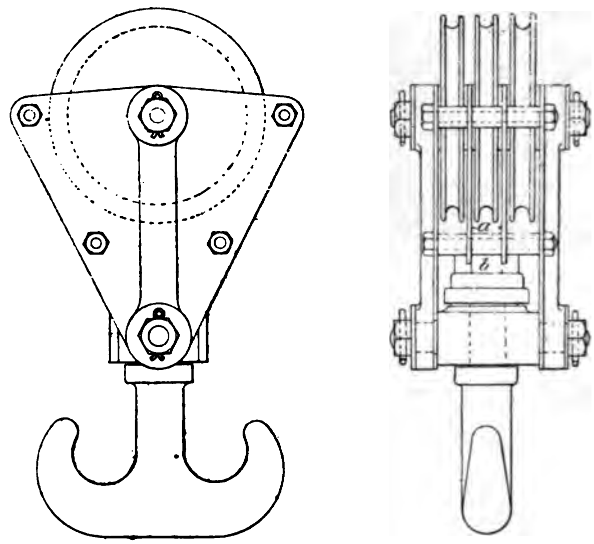


Fig. 247.—Snatch Block.

plain pieces of tube cut to length, and the bolts pass through them. The distance pieces also prevent the chain from coming off. The pulley pin is turned with a head at one end, and the other end projects through the cheek far enough to receive a split pin going through a drilled hole, and a washer behind it. The pulley, of cast iron, is made for chain. A hole is drilled diagonally through the boss for oiling. It may or may not be brass bushed, but it should be, in the bosses for the pulley pin are formed on these plates.

A heavy block is shown in Fig. 247 fitted with three pulleys. It has intermediate plates, *a*, maintained apart by distance pieces of tube, the bolts passing right through the lot. The pulley pin and the hook block are each shouldered down at the ends, and screwed to receive nuts which are retained in place by split pins. It is not necessary to take out the pins to remove a

cheek. The shank of the hook which goes through the block is threaded to receive a nut, *b*, and a split pin is passed through nut and screwed end. Washers are interposed between the nut and the top face of the block. The pulleys shown are for wire rope.

In a heavy design of block used on big block setting cranes, and on cranes in steel works, the characteristic feature is the provision given for making minute swivel adjustments through worm gear. The worm can be thrown up out of the way when loads requiring no adjustment, or light loads are being handled. The arm which carries the worm is locked with a pin both when in and out of gear.

Antifriction Devices. — These include the washers already noted, but more particularly the conical and ball races. The coned rollers are used for very heavy cranes, the ball races for others. The rollers are truncated cones, and run loosely with a slight lateral clearance in races of corresponding shapes. They are turned from a tough hard grade of steel, and so left, or in good practice are hardened and ground. They form an ideal race but are expensive.

The ball races have either vee'd or concave seatings. The old method of making the seatings with equal angles is incorrect, because some slipping and sliding must result. They should be based on a conical construction, which ensures equal rolling contact on the inner and outer radii. In the concave seatings the rolling takes place at top and bottom only. A good design of race which permits the hook to sway with the load is by the Hoffman Manufacturing Co. The balls run between rings with sloping faces confined between a casing. The lower ring slipping on its bevelled seating accommodates itself to swaying motions. The shank of the hook is also loosely fitting in the hole in its block. A washer overlapping the casing, and coming between that and the nut protects the race from weather. The block is self-contained. *See* **Ball Bearings**.

Snout Boring Machine. — *See* **Horizontal Boring Machines**.

Snug.—A lug or projection on a casting or forging, usually for receiving bolts or pins.

Soaking Pit.—A device invented by M. Gjers in 1882 to avoid the expense of reheating steel ingots previous to rolling. When attempts had been made to do this before the soaking pits were thought of, failure resulted in consequence of the interior remaining in a semi-fluid condition while the outer portions had become hardened. Either portions of the interior squirted out during rolling, or spread out more than the exterior.

M. Gjers' invention consisted simply in lowering the ingots as soon as stripped into a brick-lined pit, only a few inches larger than the ingot, and covering it in until the centre solidified, by which time the heat was distributed equally from centre to circumference, and the ingot could be rolled.

In the early practice the pits were first heated by the introduction of ingots, which were afterwards reheated until the temperature of the pits had been raised sufficiently to effect the soaking of subsequent ingots. But there were obvious objections to this. At present the pits are heated with gas, which is capable of regulation. A number of pits are built in series, and have covers. Little heating is required when the pits are in regular use.

Soap Suds.—Used for lubricating metal cutting tools.

Socket Chisel.—*See* **Chisel**.

Soda, or **Sodium Carbonate**, Na_2CO_3, crystallises in transparent, colourless crystals containing 63 per cent. of water of crystallisation, and is very efflorescent, exposure to air causing it to turn white and opaque. It is used extensively in glass-making, soap manufacture, and bleaching. The processes of manufacture of soda are described under **Carbonate of Soda**. The action of soda on the sulphate of lime present in **Feed Waters** is referred to under that title.

Softwoods.—These differ from hardwoods generally, in being soft and light in weight, but the botanical distinction is in the shape of their leaves, those of softwood trees being long and narrow, and those of hardwood short and broad. This distinction does not correctly place all the woods according to their hard or soft character from the wood-worker's point of view, but the exceptional ones are not of much commercial importance. The softwoods in general use are almost entirely varieties of pine

and fir, obtained from North Europe and North America. Most of them are known under more than one name, sometimes by that of the district they are obtained from, or by the port of shipment, and sometimes the name indicates a characteristic of the wood. The pines and firs are all very much alike in being tall, rapid-growing trees of medium diameter, the wood of which is light both in colour and in weight. Some are resinous, pitch pine being particularly so, and fir to a less extent; while others, yellow pine being an example, are not. The timber is not generally so durable as hardwood, but is cheaper, and, owing to its light weight and softness, is easy to work and to handle, and is quite suitable for many purposes, both temporary and permanent, in engineering and building. One of the best varieties is yellow pine, used in the construction of patterns. For rougher work in carpentry the cheaper and slightly harder varieties known as deal or spruce are used.

Solders, Soldering.—The union of metallic surfaces by means of an alloy which adheres to both the opposed surfaces. It includes the soft and the hard soldering, in which brazing is included. The exact way to set about any given job will vary, but the general principles are simple. The subject may be conveniently considered under the heads of the solders used, and of the methods of performing the work.

Solders.—These are termed *soft*, and *hard*, according as they are composed of tin and lead chiefly, or of alloys of copper and zinc chiefly, but the latter includes also the silver solders. As the melting points of the soft solders range from about 340° Fahr. to about 560° Fahr., these are usually fused by the heat of the copper bit. But the hard solders require a temperature so high that a coke or charcoal fire, or the blowpipe are used. It is also a more prolonged and tedious process. Numerous solders having a large range of temperature are required to suit all the metals and alloys to be united, because it is a rule that a solder must have a fusing point only slightly less than that of the material which it unites. If it has a higher melting point, the work will become fused before the solder melts. If it is much lower, the joint will be weaker than the material. This is a point of much importance when the work is subject to much stress, as in pipes and tubes, and when it has to be bent, rolled, hammered, or otherwise treated severely. For this reason tables of melting points of various alloys covering a large range are of value. It is also desirable that the colour of the solder shall as nearly as possible resemble that of the materials which it unites. These results are secured as a rule by employing similar metal or alloy in the solder as in the articles to be united, adding only a sufficient preponderance of one metal or metals to increase the fusibility.

Soft Solders.—The commonest of these is composed of 2 parts of tin and 1 of lead. It melts at 340° Fahr. The tables below give the melting points of a useful range of tin and lead solders, and of tin, lead, and bismuth with a low range of melting points.

Tin.	Lead.	Degrees Fahr.
1	10	541
1	25	558
1	2	441
1	5	511
2	1	340
4	1	365
6	1	381

Tin.	Lead.	Bismuth.	Degrees Fahr.
2	2	1	310
1	2	2	236
5	3	3	202

Fluxes.—The nature of the fluxes used is intimately related to the solders. These are necessary, because though the surfaces to be united are cleaned first, they do not remain chemically clean. At the high temperatures metallic oxides form, and unless these are dissolved, union will not take place. Hence a flux is selected which is most suitable to the

metal or alloy that is being soldered. The fluxes used are chloride of zinc, resin, tallow, sal-ammoniac, borax, and sometimes Venice turpentine, and Gallipoli oil. Some will serve for a large range of work, while the use of others is restricted.

Out of the range of solders a composition can be selected suitable for any kind of soft metal or alloy. The mixture, 2 of tin and 1 of lead, is the most widely used. It unites almost any metals and alloys, tinned iron, brass, zinc, lead, and tin. The fluxes used with this are chloride of zinc, and resin, sometimes sal-ammoniac. The two last are applied in the form of powder, but the chloride of zinc is obtained by dissolving zinc in hydrochloric acid, and using the solution. Lead is united to lead, using tallow as a flux. The solder may be the tinman's solder, or it may contain larger proportions of lead.

Hard Solders.—These are mostly the *spelter* solders, so called because zinc, or the spelter of commerce enters essentially into their composition. The ordinary mixture is 1 of copper and 1 of zinc, which is suitable for ordinary brass work. For gun-metal and copper work the proportion of copper is increased, as 16 of copper to 12 of zinc, or 3 of copper to 1 of zinc. The copper and zinc are melted together and poured into an ingot mould in small squares. These are then heated nearly to redness, and broken up with a hammer until finely granulated. These are used for iron, steel, copper, and brazing metal. Borax is the flux employed.

Methods of Soldering—Soft Soldering.—The joints employed are numerous. Some **Angle Joints** are shown under that head. Some form of lap joint is the most common. The surfaces are scraped, and dusted, or brushed with the flux. A stick of solder is taken in one hand, and the copper bit in the other, and both are drawn along in contact with each other, and with the joint. The solder is fused and follows the course of the flux. The copper bit is first heated, filed bright, rubbed on sal-ammoniac, and then on a piece of tin, after which it is wiped with tow and is ready for use.

A variation on this method is what is termed *sweating*, which is suitable for large areas. The surfaces are cleaned and coated with tin, or solder spread over with the copper bit. The surfaces are then brought together and heated until the solder fuses and unites them.

Another device is the *wiped joint*, used by plumbers for jointing the ends of pipes. Plumber's solder is composed of 1 part of tin to 2 of lead, and melts at about 441° Fahr. The lead pipes to be united are covered on each side of the intended joint with a mixture of size and lamp-black to localise the joint. The parts which are to form the actual joint are then scraped clean with the shave hook, and the clean metal rubbed with tallow. The solder is melted and poured over the joint, being prevented from running away by holding a thick cloth below, or encircling the pipe with clay. The cloth is then used to wipe or shape the joint neatly to a bulbous form, the cloth being greased. The practice of different men varies both in regard to the nature of the flux used, and its method of application. Neatness of manipulation and perfect results can only be secured by experience.

Hard Soldering.—In this the use of binding wire is generally essential, because the work takes more time than that of the soft soldering, and it is necessary to maintain the parts in contact until the operation is finished. Fine iron binding wire is used. The joint is sprinkled with crushed borax in water, and with the granulated spelter. The temperature is raised gradually to the red heat until the borax fuses, followed by the fusion of the spelter, which follows the borax into the joint. It is important to raise the temperature slowly and to graduate it carefully. If the borax boils up too quickly it will push the spelter from the joint. The borax must dry off slowly. The completion of the joint may be gauged by the blue flame which indicates volatilisation of the zinc in the spelter. Coal should not be used for heating, but coke or charcoal. A common forge may be used, or a brazier's hearth. The work may have to be tapped or *jarred* at the concluding stage to ensure the running of the spelter into the joint. When the joint is completed, the work may be removed from the fire and may be cooled in water.

In silver soldering, borax is used as a flux, and the silver is used in little square plates.

Solenoid.—An electro magnet, usually in the form of a hollow coil of wire having a movable or traversing iron core, the position of which is influenced by the intensity of the magnetic field produced inside the hollow coil when current is passed around its windings. Solenoids are used for various purposes—for example in **Arc Lamps, Gravity Ammeters,** &c. Also in solenoid magnetic brakes for cranes or other machinery, wherein the travel of the sliding core, produced when current is passed through the coils, is linked up to apply or release a friction brake to the machinery. The windings may be connected either in shunt or in series with the main circuit as may best suit the conditions. Shunt wound solenoids, for instance, are required where **Electric Braking** control is used, but where this system is not necessary, as for haulage, or for machine tool driving, the solenoid may be series wound.

Sole Plate.—Is applied to a thin bed or base-plate of cast iron. Usually it is a plain plate, without ribs or flanges, and having only stops for plummer blocks on top, and joggles on the bottom to fit into timber balks. It is used for winding gears chiefly.

Solid.—The difference between the three states of matter—solid, liquid, and gaseous—is merely a difference in degree of molecular motion. It is entirely a question of the extent to which molecular attraction is permitted to exert itself. When these molecules have perfect freedom of motion, parting company and traversing space, matter is in the state known as a gas. When their freedom of motion is more limited, and they mutually exert attraction much as the sun attracts the earth, and the earth the moon, the gaseous is transformed into the liquid state. In the solid state the molecules of matter are still further limited in motion, and their mutual attraction is still greater, so that the motion becomes one of vibration between groups of molecules. The state in which matter occurs, therefore, depends on the kinetic energy of its molecules. Science is at present ignorant of the nature of this force, but probably it will ultimately be found to be an electrical phenomenon. Instead, therefore, of regarding solids, liquids, and gases as three distinct states of matter, it would be more scientifically correct to regard them rather as three stages in a series of graduated changes.

Speaking generally, gases expand more than liquids when heated, and liquids more than solids. As solids have a definite shape, a distinction is made between linear, superficial, and cubical expansion. Whatever fraction of its length, surface, or volume the solid expands for 1° Cent., is its linear, superficial, or cubical coefficient of expansion. As the coefficients of different solids vary, it is frequently necessary in engineering practice to resort to **Expansion Devices.**

Solid Blows.—Hammer blows which are delivered on an object, opposed to which is the resistance of an anvil or stake. The term is used to denote the opposite of unopposed, or hollow blows, employed in raising works. These tend to thicken sheet metals, while solid blows thin them.

Solid Columns. — Columns or pillars in which the metal is massed solidly, a form which is restricted mostly to those of small diameter, and of timber. The hollow form is more economical in large diameters, in cast iron, and in the built-up Phœnix type. The strength of a hollow column nearly equals the difference between that of two solid columns, the diameters of which are equal to the external and internal diameters of the hollow one. For the strength of columns *see* **Columns.**

Solid Couplings. — Couplings which are forged solidly on their shafts, as in propeller shafts, and occasionally in line shafting. Also the solid muff form. *See* **Shafting.**

Solid Drawn Tubes.—*See* **Tubes.**

Solid Emery Wheel.—The common wheel made wholly of emery, as distinguished from the wooden wheel, or the lead lap, in which the periphery only is charged with emery.

Solid Lubricants.—The substitution of a solid lubricant for fluid oils and tallows, and commercial mixtures would do away with considerable expense incidental to the use of oil cups, tubes, and lubricators, and with the difficulties consequent on decomposition, &c. Comparatively little has been done yet in this way.

As the function of any lubricant is to effect a separation of the surfaces in contact, it would

appear as though a solid lubricant must be more efficient than even the heavy viscous oils. Plumbago has long been used to a limited extent for lubricating the old hardwood bearings, which thus acquire a hard, glossy, and durable surface. Later it has been mixed with other substances and packed in grooves similarly to asbestos.

A form of lubricant which has been experimented on largely by the Franklin Institute, is fibre graphite. It is composed of finely ground plumbago mixed with wood fibre in a moist condition, and pressed into a mould of any required form. It is then saturated with a drying oil, and oxidised in hot dry air.

A preparation of graphite which has been very favourably reported on is that supplied by the Joseph Dixon Crucible Co., of Jersey City, N.J. The crystalline form is the one used, as the amorphous is usually contaminated with clay and gritty particles. The flakes of graphite are extremely thin, ranging from about 0·001 in. to 0·0002 in., or on an average about one-tenth the thickness of ordinary writing paper. This fills up minute roughnesses on the surfaces of bearings, and attaches itself to the surfaces. It is used alone in very light bearings, but is mixed with oil for heavy bearings in the proportion of from 2 per cent. to 8 per cent. of graphite to oil, according to conditions. The graphite fills up all pits and irregular surfaces, and produces a smooth veneer which is dense, hard, and durable, and prevents abrasion. It has been proved suitable for gas engine cylinders at temperatures of from 2,000° to 3,000° Fahr., at which ordinary oils are nearly useless. Heat has no effect on graphite. It is suitable for the bearings of rolling mills, ladle gears, and heavy and hot duty generally. Numerous experiments have shown a great reduction in friction by the use of graphite. Thus Prof. Kingsbury, testing the friction of screws, showed the following :—

Lubricator.	Minimum.	Maximum.	Mean
Lard oil (heavy machinery)	0·09	0·25	0·11
Oil, mineral ,, ,,	0·11	0·19	0·143
Oil and graphite (equal volumes) - - -	0·03	0·15	0·07

Solid Tools.—The common metal cutting tools which are forged in one with their shanks, and are thus distinguished from the tool points held in tool holders.

Solution.—Perhaps the best definition of a solution is "a homogeneous mixture of heterogeneous molecules, which allows no separation of its constituents by mechanical means." In its full sense a solution may be a mixture of gases, a gas, liquid or solid dissolved in a liquid, or a gas or solid dissolved in a solid. The solubility of different gases, liquids, and solids in liquids varies widely. A given volume of water, for example, absorbs twice as much oxygen as hydrogen, forty-five times as much carbon dioxide as oxygen, and five hundred and eighty times as much ammonia as oxygen. Liquids, too, are miscible with one another in varying degrees, while common experience shows to what an extent the solubility of solids in liquids varies. In the latter case a point is generally reached at which the liquid refuses to absorb any further amount of the solid, and the solution is then said to be saturated. The saturation point, however, depends on the temperature, the quantity dissolved increasing as the temperature rises, but at different rates with different substances. (In the case of gases, however, solubility diminishes with a rise in temperature; in fact, the heating of a liquid is resorted to in order to expel contained gas.) The solution of a solid in a liquid is generally accompanied with absorption of heat; sometimes, as in a chemical solution, *e.g.*, zinc in sulphuric acid, a rise in temperature takes place.

The weight of a gas dissolved by a liquid increases in proportion to the pressure under which it is dissolved, which is an obvious deduction from Henry's Law that a liquid at a given temperature dissolves the same volume of a gas at all pressures.

On cooling or evaporating a saturated solution, the excess of solid dissolved resumes its previous state and usually assumes a definite geometrical shape termed a crystal. *See* **Crystallography**.

The peculiar absorption of gases by platinum and palladium may be regarded as examples of solution, and it is a question whether we should not regard steel as a solution of carbon in iron.

There is, in fact, much speculation as to the state in which a substance exists when dissolved in another, and the nature of the changes it undergoes. The subject is equally as interesting to the biologist as to the chemist, and it has been said that "the application of physical conceptions to the problem of living matter chiefly depends on the knowledge we possess of the physics and chemistry of ordinary solution." Summarising the most generally accepted and most probable theory of solution, it is believed that some of the molecules of a dissolved substance break up into ions, which wander aimlessly through the liquid. Thus, salt, NaCl, in dissolving breaks up into ions of sodium and ions of chlorine. One of these ions, sodium, is positive, and is called a kation; the other, chlorine, is negative, and is termed an anion. On passing an electric current through the solution the ions immediately commence travelling in opposite directions, the kation drifting with the current to the kathode, and the anion going towards the anode. This theory fits in very well with the facts of electrolysis. It also serves to explain the phenomenon of chemical precipitation. Silver nitrate, $AgNO_3$, gives a white precipitate with hydrochloric acid, HCl; the hydrogen and silver ions are positive, and the chlorine and acid radical ions are negative, and by the combination of the silver and chlorine ions a new substance is formed, which is insoluble, and is therefore precipitated. These facts may be graphically represented in the equation—

$$\overset{+\ -}{HCl} + \overset{+\ -}{AgNO} = \overset{+\ -}{AgCl} + \overset{+\ -}{HNO}$$

the silver chloride, AgCl, being the precipitate.

The solubility of certain substances is put to practical use in purifying them by crystallisation or filtration from solution, and also in separating substances from one another which differ in the degree of their solubility.

Solution Theory.—The theory that solid solutions of alloys behave similarly to saline solutions of water. *See* **Alloys**, and **Eutectic Alloy.**

Soot Doors.—The doors at the front ends of the brick-work flues of Cornish and Lancashire boilers through which the accumulations of soot are withdrawn.

Sorbite.—A term applied to a condition of steel which lies between cementite and ferrite in unhardened steel, and between cementite and martensite in hardened steel. It shows no striæ under the microscope.

Sow.—The main channel in the pig bed coming from the blast furnace, and which is a feeder to the pig moulds.

Sowers.—Machines for depositing seeds in a regular manner over large areas. Hoppers are carried on a framework which runs on the ground through the medium of rollers, and a feed mechanism allows the seeds to escape in a regular manner. The feed in some cases consists of a brass slide, while in others a revolving disc perforated with holes regulates the flow of seed. The rotation of the shaft actuates bevel gears coupled up to the disc, which is thus rotated as long as the sower travels. The rollers are broad, and concave, so that they close in the soil around the seeds. The broadcast sowers, used chiefly for grain and grass seeds, have a long box which slides to and fro in a frame, perforated with holes, through which the seed escapes. The reciprocation is transmitted to the box by gears from the axle. Small sowers are moved by hand, larger ones by animal power.

Spacing.—Signifies, generally, the setting out or pitching of divisions on work, such as holes for bolts and rivets, positions of bearings, brackets, and fittings.

Spall, Spalling.—The accidental breaking out of chips in timber or metal.

Spandrel.—That part of an arched structure which is enclosed by the outer part of the curve, the horizontal, and end vertical members. It is lightened in masonry, and filled in with ornament in an iron structure.

Spanner.—A bar having an opening or openings to fit a nut or screw, and a handle by which sufficient leverage is obtained. Spanners are made of wrought iron, wrought steel, and cast steel, and are case-hardened in the better classes, to withstand hard usage, and retain their dimensions unaltered.

The simplest spanner or wrench is a plain bar, having an opening cut at the end to fit the nut on two sides, Fig. 248, A. The handle portion is usually thinned down and tapered off.

Special spanners which are used by boiler-makers and platers, B, have long handles, ending in a podger, which is useful for pulling work into line, and generally adjusting plates, &c., without using the hands. Platelayers also make use of long handled spanners, to avoid stooping.

For general work, spanners are angled, so that the mouth stands at 15° to the handle, Fig. 248, C; the object of this is to enable hexagon nuts to be turned in confined situations. Thus a nut can be turned completely around where the swing of the handle is limited to 30°, as seen in D. This cannot be done with a straight spanner, on account of its fouling the sides of the work enclosing the nut. When one spanner is constantly in use on the same sizes of nuts, as in a lathe or machine, the single-end type is satisfactory, but when a number of different sizes are dealt with, it is better to have double-ended spanners, so that the total number is lessened. Such spanners are usually angled, E, and are often cranked into an S-shape, F. For square nuts the jaw form is modified, G, these being made in the same shapes as those for hexagon nuts.

A better fit on the nuts, without risk of slipping, is obtained by the closed-in or box spanners H for hexagon, and J for square nuts. These are largely employed for lathe tool posts, shaper tool-box screws, &c., where the spanner is in frequent request. A combination of two hexagon ends, or a square and hexagon, or an open and a closed square is common, K. When nuts are sunk below surfaces, a cranked spanner is necessary, *see* L and M. But if these cannot be used, the box spanners shown in succeeding

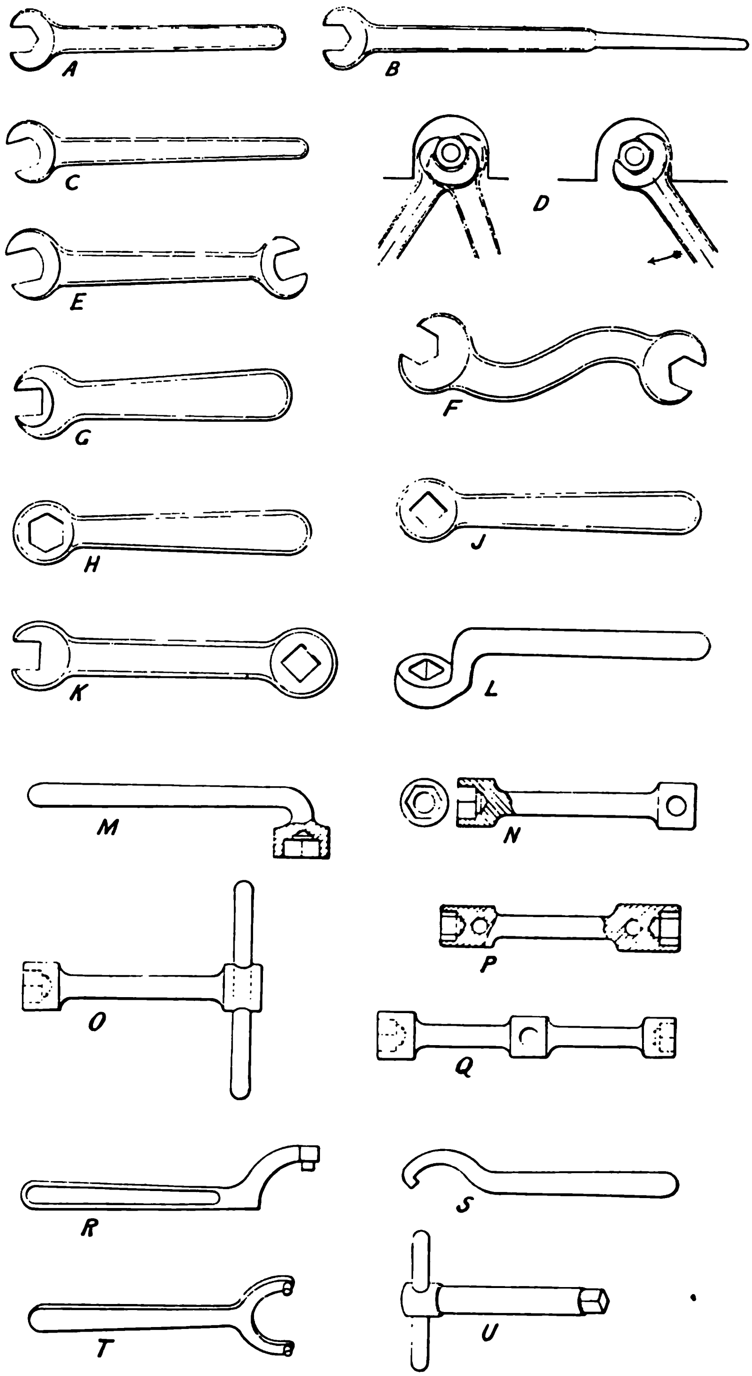


Fig. 248.—Spanners.

figures are employed. N and O can be used without requiring a horizontal space above the nut for the sweep of a handle; a podger inserted in the hole at the end of the shank N, turns it. Frequently a cross-bar is permanently fixed in the head O. Double-ended types, as at P and Q, are made, while a specially heavy pattern is formed out of a solid lump.

Nuts other than square and hexagon have either transverse holes drilled in them, or longitudinal slots cut down the body. In the first case the tommy is hooked, R, with a pin end to enter into the holes, in the second, S, a bent end engages in the slots. These are used extensively on machine tools, where such nuts are fitted to spindles, screws, &c., for adjusting purposes. T is used for nuts having holes in the faces, and U for hollow-ended screws such as are employed in chucks.

Adjustable spanners, or wrenches, or monkey wrenches are useful for work where it is not convenient or desirable to have a large number of various sizes on hand, and on outdoor work. A simple method of rendering a spanner adjustable is to fit it with a sliding jaw, secured in any position with a wedge hammered up tightly. Such spanners are made in large sizes for dealing with big nuts, and they are very suitable for such work. But on the smaller tools some form of screw adjustment is essential, and there are several ways of effecting this. The Clyburn type, Fig. 249, A, has a sliding jaw moved to and fro by a short worm, engaging in teeth on the back of the jaw. This gives a very solid and firm construction. Direct screw action is largely employed, in types like the Coach type, B, in which the sliding jaw is drawn back and forth by a screw turned by a screwed handle. In the Coes type, C, the sliding jaw is moved by a screw and nut. The handle is forged into a flat or knife form, covered on each side with wood. In the largest patterns the screw is adjusted from a sliding block, secured with a wedge, D. In the Billings tools, E, the sliding jaw fits right inside the handle portion, and is moved by a nut encircling the screwed tail of the jaw.

Ratchet wrenches are constructed on a similar principle to the ratchet braces; they save a good deal of time, which would be otherwise occupied in taking off and putting on a spanner to turn a nut in an awkward situation.

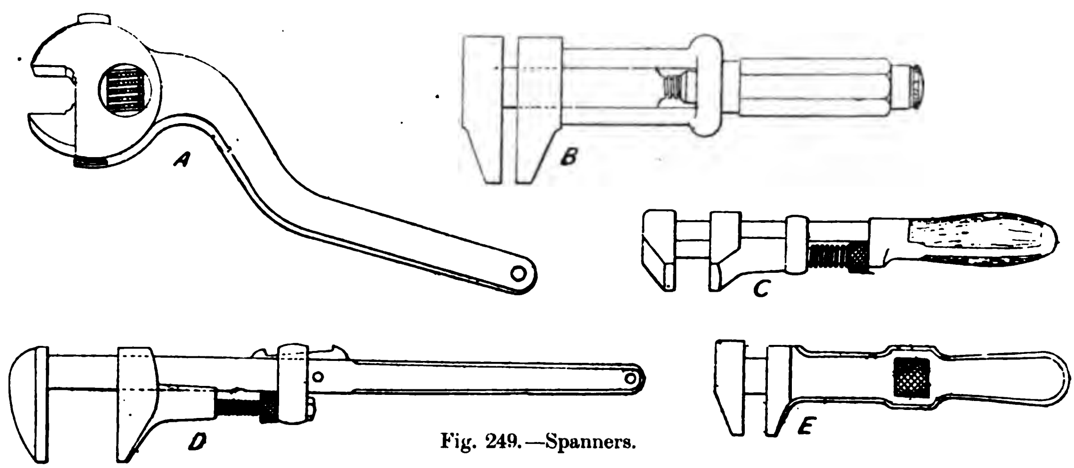


Fig. 249.—Spanners.

Spare Parts, Spare Gear.—It is usual in the case of all prime movers, machines, and machinery in which some parts are subjected to excessive and rapid wear, or to risk of fracture, to include the supply of spare gear to replace those parts. The object in view is to avoid lengthened breakdowns and delays which would be entailed by having to wait while new parts were being ordered. In the case of vessels it becomes an absolute necessity if the risks of partial or total disablement are to be avoided. It is also of much greater importance in machinery delivered to the Colonies and foreign countries than at home. The principal kinds of

machines for which spare parts are supplied are cranes of all kinds, mining machinery, especially stamps, builder's and contractor's machinery, steam engine parts, pump parts, pneumatic tools, and above all marine engine fittings. The last is so important that the Board of Trade and Lloyd's insist on a certain number of articles of spare gear being carried in all steam vessels which are classed in the Register books, besides which others are recommended to be taken.

Spark Arrester.—Objection is sometimes made to the employment of traction engines, on the ground that sparks flying therefrom are liable to cause fires. Many are therefore fitted with a device for preventing escape of the sparks. The commonest is to surround the top of the chimney with a wire cage, which may be relied on to effect its purpose when coal or wood are used. When straw is used, something more efficient is required. In one design a dome-shaped cap is fitted above the chimney, coming down into a water pocket surrounding it. The sparks are thus thrown down into the water and extinguished. Messrs Ruston, Proctor, & Co., Ltd., fit a chimney base which can be also used as a water spark arrester. It is fitted at the base of the chimney. A deflecting plate throws the sparks down into a water chamber, and prevents them from entering the chimney.

Another is the Strube. It comprises an enlarged hood enclosing a conical deflector against which the sparks striking, are thrown downwards. To prevent risk of high winds drawing the sparks out, a guard is fitted round the top, and is kept facing the direction of the wind by being pivoted to a weather vane.

Specifications.—The documents by which manufacturers are bound to carry through work. They embrace everything which relates to the materials, workmanship, tests, inspection, and time limit; and tenders are given in accordance with specifications. To some extent this subject is covered by articles in these volumes dealing with materials, tests, and workmanship, but the following remarks relate to some aspects of shop specifications.

Every section of engineer's work has its own particular class of specification, as for castings, boiler work, machining, and fitting; specifications covering the complete motor or machine, defining the powers of the inspector, the nature and severity of the tests, and so on. And they are very strict, so strict sometimes that firms do not care to tender, or if they tender their estimates are higher. Or the specification may be in moderate terms only. Tests may be imposed, or they may be invited and submitted. Some specifications when drawn up by unpractical men are ridiculously unreasonable, if not impossible to comply with. Others are prepared on broad and reasonable lines permitting of variations subject to the approval of the inspector. The following are a few notes extracted from specifications.

General.—"The materials, workmanship, and finish of the engines and pumps are to be respectively the best of their kind, and no part is to be of less strength than is equal to at least ten times the maximum pressure of steam on the pistons. Should it appear to the engineer that the contract is not being fulfilled in this respect, the contractor is to substitute such other materials as may be approved by the engineer; and in the event of the workmanship of any portion of the work executed being, in the judgment of the engineer, imperfect or defective, or not in accordance with the terms of the contract, such portion shall be removed, and the work executed in a manner which shall meet with the approval of the inspector."

Quality of Materials, and Workmanship.—"The castings shall be clean externally and sound internally, and shall be carefully fitted. Cylinder liners and pump working barrels shall be made of mottled grey and white iron as hard as can be bored, and shall be bored out perfectly parallel and truly cylindrical throughout. No stopping or plugging shall on any account be permitted, in case of any holes or flaws appearing; nor shall any portion of the castings be made in open sand. All bolt holes must be bored out of solid metal, no cores being used. The metal (the whole of which must be remelted in the cupola) shall be free from any admixture of cinder iron, or any other inferior material, and shall be uniformly tough and close grained, and of such strength that a turned bar having an area of 2 sq. in. shall bear a tensile strain of not less than 18,000 lb. per sq. in. without breaking.

"The gun-metal to be free from specks and blow-holes, and of a quality to be approved by the inspecting officer. The copper must be free from cracks, seams, and flaws, and bear without breaking a tensile strain of 13 tons per sq. in. of original section, with a reduction of area at the point of fracture of not less than 20 per cent."

Or.—"All the bearings and other parts specified to be of gun-metal shall be made of a strong and durable mixture of pure copper and tin, no lead, zinc, antimony, spelter, or old metal being used therein. And in order to ensure equal wear, each set must be cast at once with one mixture at one melting, in order to be as nearly as possible of a uniform quality, degree of hardness, and colour. All bearings of phosphor bronze to be of a mixture or brand to be approved by the inspector."

Steel.—"A specification of the steel, whether cast, rolled, or forged, must be submitted (or the tests of Lloyd's, the Board of Trade, or other bodies may be specified; or the brands of certain manufacturers) giving the maximum and minimum tensile tests, reduction of area, elastic limit, and cold and hot bending tests, from samples cut from the materials to be used. Steel castings to be carefully annealed."

Wrought Iron.—"Wrought iron must be soft and fibrous, well made and free from lamination, and uniform in texture, and a specification of the tests to which it will be subjected must be submitted."

Copper Pipes.—"The whole of the copper pipes connected with either engines, boilers, or pumps are to be of the very best solid drawn copper of the thickness figured on the drawings. Where not protected with non-conducting compositions they are to be got up dead bright. The flanges of the main feed pipes are to be of gun-metal, the ends of the pipes being riveted into a recess turned in the face of the flange, to which they are also to be securely brazed, care being taken that the spelter is drawn through the whole depth of the joint."

Workmanship — Jointing.—"Every flanged joint is to be drilled with twist drills in place, and fitted with turned steel bolts, an easy driving fit. The cylinder joints, pipes, cocks, flanges, or other joints (excepting those on the main pumps and their pipes) are to be carefully scraped to a true surface in order to make a perfectly tight joint with boiled oil only."

Flanges.—"The flanges of all pipes of the same size are to be drilled from a templet, so that they shall be interchangeable."

Bolts, &c.—"All bolt holes are to be accurately laid out and drilled. All screw bolts, pins, and washers to be accurately made and turned, and the threads to be satisfactory to the inspector."

Cocks.—"The whole of the plug cocks used about either engines or pumps are to be of gun-metal, asbestos packed, and of Dewrance's or other approved make. The whole of the sluice cocks are to be of the company's standard pattern and weight."

Tests.—"Tests are all to be done at the contractor's expense. All testings ordered to be performed on the contractor's premises are to be done by him at his own expense both as regards labour and material, under the direction of the inspector. Samples for testing elsewhere are to be sent to such place as the inspector shall direct. The expense of such tests if they prove satisfactory will be borne by Messrs ——, and the contractor will be allowed such fair value of test samples, including their carriage, as the inspector shall decide. In the case of tests which prove unsatisfactory, the contractor will be charged with all expenses both of testing and carriage, and nothing whatever will be allowed for the samples. In case of a sample under the test proving unsatisfactory to the inspector, all the material represented by it will be condemned as unfit for use in the work, and will be rejected."

Test after Erection.—"On the completion of the erection at the works, or at its destination, the machinery shall be tested and any defect then observed which can be traced to the workmanship or material supplied will be made good by the contractor free of all expense to the purchaser."

Painting.—"All bright surfaces of the steel and iron work to be kept greased or oiled and free from rust whilst in the contractor's hands. All other surfaces to be oiled before being put together and to be painted with two coats of approved oil colour before leaving the contractor's works."